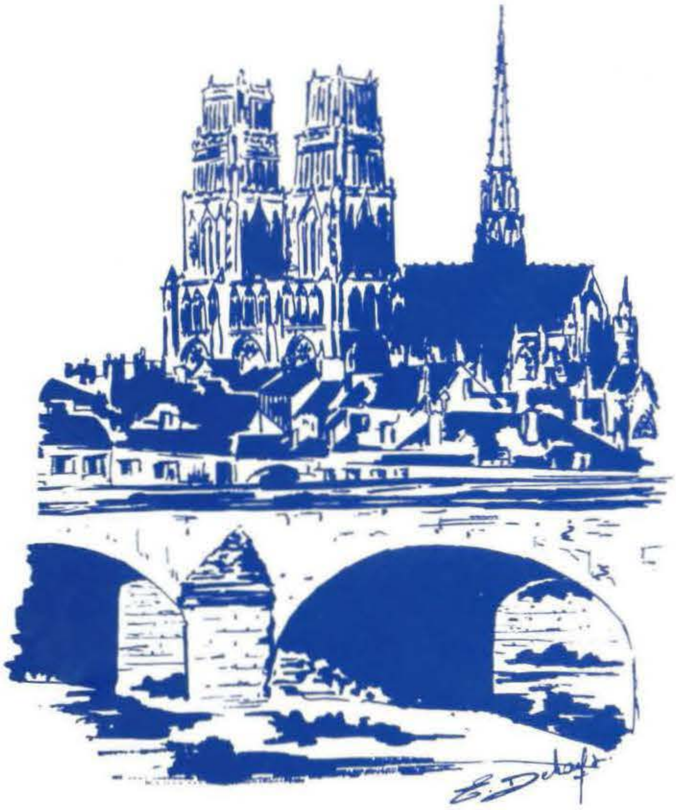
E COLLOQUE INTERNATIONAL
EXPLORATION GEOCHIMIQUE
COLLOQUE SUR LES METHODES
PROSPECTION GEOCHIMIQUE

12 TH INTERNATIONAL GEOCHEMICA
EXPLORATION SYMPOSIUM
4TH SYMPOSIUM ON METHODS
OF GEOCHEMICAL PROSPECTING



Avec le concours
d'Orléans Congrès

*With collaboration
of Orléans Congrès*

12e colloque international d'exploration géochimique

4e colloque sur les méthodes de prospection géochimique

12th international geochemical exploration symposium

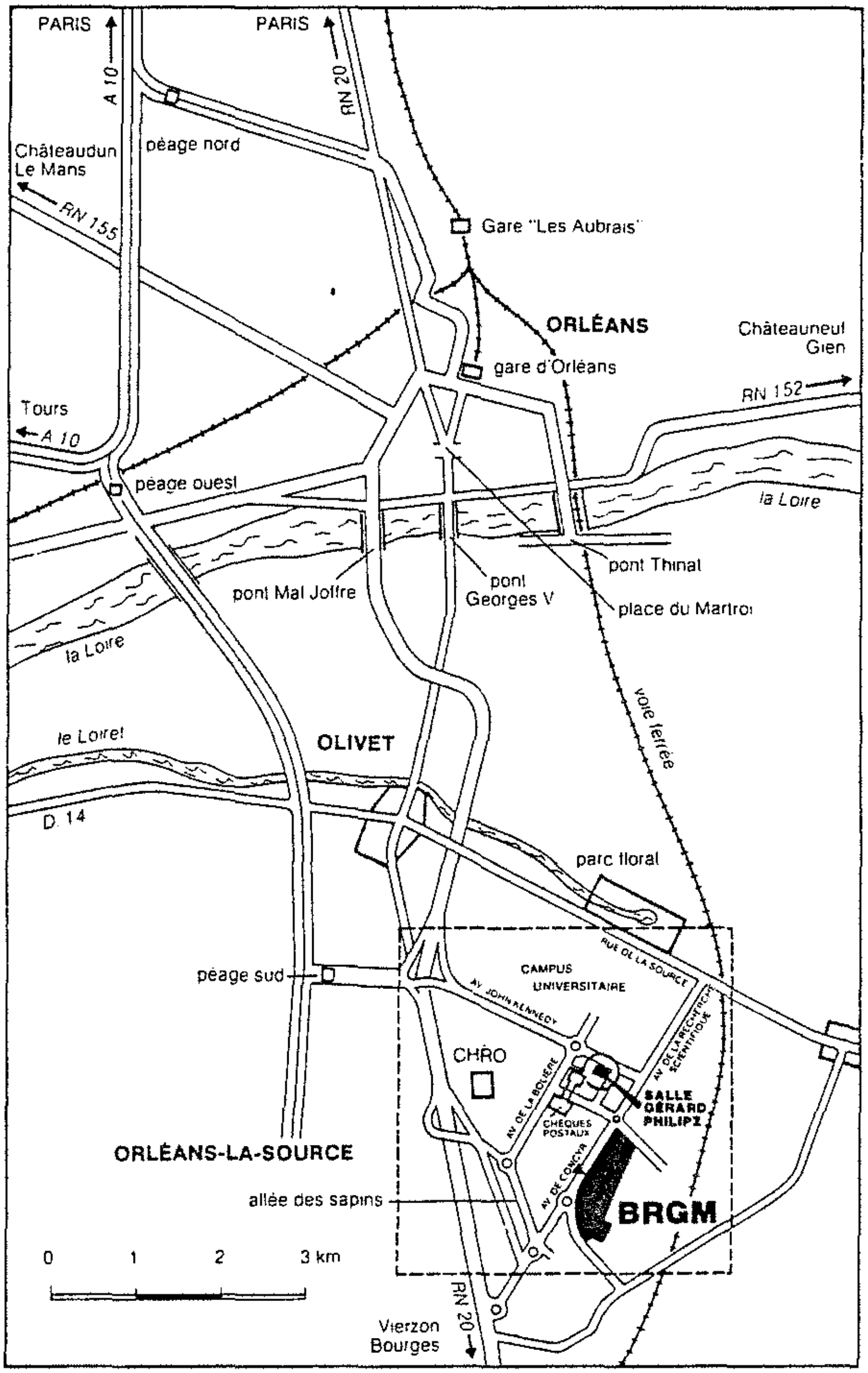
4th symposium on methods of geochemical prospecting

BRGM

BUREAU DE RECHERCHES GÉOLOGIQUES ET MINIÈRES

accès au brgm

how to get there ?



MAIN CONFERENCE ROOM
SALLE GÉRARD PHILIPE
AVENUE J.F. KENNEDY
ORLÉANS-LA-SOURCE

B.R.G.M.
AVENUE DE CONCYR
ORLÉANS-LA-SOURCE
TÉL. 38.64.30.08

PROGRAMME ET RESUMES
PROGRAMME AND ABSTRACTS

ADRESSE PERMANENTE :

Comité d'Organisation du Colloque de Prospection
12e IGES - 4e SMGP
BRGM - BP 6009 - 45060 ORLEANS Cédex 02 FRANCE
Télex : 780 258 F - Téléphone : 38.64.30.08
Télécopieur : 38.64.35.18

SALLE DE CONFERENCE :

Salle Gérard Philippe
Avenue J.F. KENNEDY - ORLEANS -La Source
Téléphones : 38.63.05.56, 38.63.05.83, 38.63.06.25

ADRESSES DES HOTELS :
HOTEL ADDRESSES

ABEILLE ET COMMERCE - 32, rue de la République - ORLEANS
tél. 38.53.54.87

ARCADE - 4, rue du Maréchal Foch - ORLEANS
tél. 38.54.23.11

FRANTEL - 643, rue de la Reine Blanche - OLIVET
tél. 38.66.40.51

IBIS - Chemin des Sablons - SARAN
tél. 38.73.39.93

JACKHOTEL - 18, Cloître St-Aignan - ORLEANS
tél. 38.54.48.48

DU SAUVAGE - 71 et 102, rue de Bourgogne - ORLEANS
tél. 38.62.42.31

LES CEDRES - 17, rue du Maréchal Foch
tél. 38.62.22.92

NOVOTEL - 2, rue Honoré de Balzac - ORLEANS -La Source
tél. 38.63.04.28

SAINT AIGNAN - 3, place Gambetta - ORLEANS
tél. 38.53.15.35

SOFITEL - 44-46, quai Barentin - ORLEANS
tél. 38.62.17.39

LE MOT DES PRESIDENTS,

Il nous est très agréable, au nom du Comité d'Organisation, de souhaiter la bienvenue à tous les participants au Colloque International de Prospection Géochimique.

Vous représentez plus de 40 nations, ce qui illustre le bien fondé d'un colloque commun, rassemblant les membres de "l'Association of Exploration Geochemists" et ceux de "l'International Association for Geochemistry and Cosmochemistry", groupe de travail : prospection géochimique.

Nous espérons que le programme technique et les échanges qu'il suscitera vous intéresseront et vous ouvriront des perspectives nouvelles pour l'exploration minière, mais qu'ils vous ménageront néanmoins quelques loisirs pour les visites, les réceptions et les soirées.

Nous exprimons nos vifs remerciements à la Direction Générale du BRGM qui a bien voulu accepter, malgré une conjoncture difficile pour l'industrie minière, d'organiser et d'accueillir ce Colloque à Orléans.

Que les membres du Comité d'Organisation et tous nos collègues du BRGM qui ont activement participé à la préparation et, nous le souhaitons, à la réussite de cette manifestation, reçoivent toute notre gratitude.

WELCOME FROM THE CHAIRMEN,

On behalf of the Organizing Committee it is our pleasure to welcome all registrants at the International Geochemical Exploration Symposium.

You represent more than fourty nations, justifying the organization of a Symposium co-sponsored by the Association of Exploration Geochemists and the International Association of Geochemistry and Cosmochemistry, working group geochemical prospecting.

We hope that you will be interested and stimulated by the technical program, as well as by the informal discussions, but with some time left for the proposed social activities.

We express our gratitude to BRGM General Management, for accepting the organization of the Symposium, in spite of the present difficult climate for Mineral Exploration.

We also thank the members of the Organizing Committee and our BRGM colleagues for their active contribution in the preparation of this International Symposium.

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INFORMATIONS GENERALES

Le 12ème Colloque international d'Exploration Géochimique et le 4ème Colloque sur les méthodes de prospection géochimique sont organisés par le Bureau de recherches géologiques et minières (BRGM) à Orléans -La Source - France - du 23 au 26 avril 1987.

Ces deux Colloques sont patronnés par "l'Association of Exploration Geochemists" (A.E.G.) et par "l'International Association of Geochemistry and Cosmochemistry" (IAGC), groupe de travail "prospection géochimique".

Accueil. Le bureau d'accueil et d'inscription est installé dès le 22 avril et pendant toute la durée du Colloque. dans le hall de la salle de conférence "Gérard Philipe" à Orléans -La Source.

Les présentations orales se dérouleront dans la salle de conférence "Gérard Philipe" du jeudi 23 avril au dimanche 26 avril 1987.

Les séances posters seront organisées les 23, 24 et 25 avril dans les salons du BRGM entre 12:30 et 14:30. Une séance spécialisée est programmée le jeudi soir 23 avril de 17:15 à 18:30 - avant la soirée "Vins et fromages de France".

Les expositions commerciales se tiendront pendant toute la durée du Colloque et suivant les mêmes horaires, dans la salle d'exposition située à proximité de la salle de conférence.

Les ateliers du mercredi 22 avril auront lieu dans les locaux du BRGM suivant une répartition indiquée dans le programme technique.

La réunion annuelle du Comité de l'AEG aura lieu le samedi 25 avril de 12:00 à 13 :00 dans la salle G. Philipe.

La réunion annuelle du groupe de travail " prospection géochimique" de l'IAGC se tiendra le vendredi 24 avril de 13:30 à 14:30 dans le salle G. Philipe.

Transports. Un service de car assurera tous les jours, mercredi 22 avril inclus, le transport aller-retour des congressites des hôtels à la salle G. Philipe et de la salle G. Philipe au BRGM (ateliers, repas, séances poster).

Voyages. Les participants au Colloque trouveront auprès de "Auxi-Voyages", dont l'agence est située à proximité immédiate de la salle G. Philipe (renseignements à prendre à l'accueil) toutes les facilités pour l'organisation de leur voyage.

Caisse. Le caissier comptable du Colloque sera à la disposition des participants pour tous paiements ou remboursements des divers frais d'inscription, les matins du 23, 24 et 25 avril de 8:30 à 12:30, dans le hall de la salle G. Philipe.

Badges. Chaque participant ou membre accompagnant inscrit au Colloque recevra un badge nominatif nécessaire pour accéder aux salles de conférence et d'exposition et participer aux réceptions et visites.

Repas. Un déjeuner sera servi au restaurant du BRGM les 22, 23, 24 et 25 avril de 12:30 à 13:30. A l'arrivée des cars, les congressistes sont priés de se répartir entre les salons BRGM (posters) et le restaurant afin de réduire la file d'attente pour le déjeuner. Le café sera servi dans les salons.

Rafraichissements. Café, thé et jus de fruit seront mis à la disposition des participants lors des "pauses-café" indiquées au programme technique.

GENERAL INFORMATION

The 12th International Geochemical Exploration Symposium and the 4th Symposium on Methods of Geochemical Prospecting are organized by the Bureau de Recherches Géologiques et Minières (B.R.G.M.) at Orléans-La Source, France, from April 23 to 26, 1987 under the sponsorship of the Association of Exploration Geochemists (A.E.G.) and the International Association of Geochemistry and Cosmochemistry (I.A.G.C.), working group "Geochemical prospecting".

Registration and information desk will be opened on April 22 and during the whole duration of the Symposium in the entrance hall of the "Gérard Philipe" conference room at Orléans-La Source.

Oral presentations will be held in the "Gérard Philipe" conference room from Thursday, April 23 to Sunday 26, 1987.

Poster presentations will be held in the B.R.G.M. lounges from 12:30 to 14:30, April 23, 24 and 25. A special session will be held on Thursday, April 23 from 17:15 to 18:30 before the wine and cheese reception.

Exhibition booths will be opened during the whole duration of the Symposium in the exhibition room near the main conference room.

Workshops will be held in the B.R.G.M. conference rooms on Wednesday, April 22. See technical program for further information.

IAGC annual meeting of the working group "Geochemical prospecting" will be held in the "Gérard Philipe" conference room from 13:30 to 14:30, Friday, April 24.

AEG annual meeting will be held in the "Gérard Philipe" conference room from 12:00 to 13:00, Saturday, April 25.

Transportation. Two-way bus facilities will be available every day including Wednesday, April 22 from hotels to the "Gérard Philipe" conference room and from the conference room to the B.R.G.M. (workshops, meals and poster sessions).

Homeward journey. Delegates may contact "Auxi-Voyages" travel agency near the "Gérard Philipe" conference room (for further information see registration desk) for the organization of their homeward journey.

Cashier's desk. The Symposium cashier will be at the disposal of delegates for all payments and refunds of various registration fees, from 8:30 to 12:30, April 23, 24 and 25 in the entrance hall near the "Gérard Philipe" conference room.

Badges. A personal badge will be given to each delegate or registered member for access to the conference and exhibition rooms and participation to receptions, visits and tours.

Meals. Lunch will be served at the B.R.G.M. cafeteria from 12:30 to 13:30, April 22, 23, 24 and 25. Delegates are asked to divide into groups between the B.R.G.M. lounges (posters) and cafeteria in order to avoid queuing. Coffee will be served in the lounges.

Drinks. Coffee, tea and refreshments will be served to delegates during "coffee breaks" as indicated in the technical program.

EXCURSIONS

EXEMPLES DE PROSPECTION GEOCHIMIQUE EN BRETAGNE
(Ouest de la France)

A1 : 19-21 avril
A2 : 27-29 avril

L. LAVILLE-TIMSIT, R. VASQUEZ-LOPEZ

L'accent sera mis sur les apports de la prospection géochimique multi-éléments, aux diverses échelles d'investigation, dans l'exploration d'une région caractérisée par une importante couverture pédologique. On visitera :

- des prospects d'amas sulfurés polymétalliques dans le Paléozoïque (régions de Nantes et Saint Brieuc) ;
- un stockwerk à Au contrôlé par une "shear-zone" (région Angers) ;
- des minéralisations W-Sn-Mo-Ag-As de type porphyrique (région de Nantes) ;
- des filons à antimoine découverts sous recouvrement de limons (région de Nantes).

MINE D'OR DE SALSIGNE ET MINE (Zn-Pb) DES MALINES
(Sud du Massif Central)

B2 : 26-29 avril

M. BONNEMAISON, F. TOLLON, Ph. LAGNY

Située dans les formations volcano-sédimentaires cambriennes du Sud de la Montagne Noire, la Mine de Salsigne a produit 80 t d'Au. La visite en mine et en carrière montrera les différents types de minéralisation : couches sulfo-arséniées de type Sedex. disséminations dans des grès quartzites, concentrations filoniennes tardives. Les données géochimiques disponibles sur le district aurifère seront discutées.

Le gisement des Malines, d'où l'on a extrait 800 000 t métal, est un paléorelief carbonaté cambrien recouvert en transgression par le Trias ; les concentrations Pb-Zn montrent en particulier de beaux exemples de remplissages paléokarstiques minéralisés.

Une visite de la cité médiévale de Carcassonne, réputée pour ses remparts du 12e siècle, agrémentera cette tournée.

GISEMENTS PERIDIAPIRIQUES A Pb-Zn DU NORD DE LA TUNISIE

F2 : 26-30 avril

J.J. ORGEVAL, A. GUEDRIA

Cette excursion sera axée sur la démarche de la découverte récente des concentrations Zn-Pb de Bou Grine dans laquelle l'outil géochimique fut largement impliqué. Seront soulevés en particulier les problèmes spécifiques des zones semi-arides où la présence de calcrètes et de matériaux éoliens atténue les réponses géochimiques.

La visite de Bou Grine (surface et mine) sera complétée par celle des exploitations de Bou Jaber et de Fedj el Adoum - gîtes Zn, Pb, Ba, F.

Une visite touristique des sites de Carthage et des ruines romaines de Dougga est également programmée.

FIELD-TRIPS

GEOCHEMICAL EXPLORATION CASE HISTORIES IN BRETAGNE (Western France)

A1 : April 19-21
A2 : April 27-29

L. LAVILLE-TIMSIT, R. VASQUEZ-LOPEZ

Emphasis will be placed on sampling problems at different exploration scales, and on the role of multielement geochemistry in the mineral exploration of a region which is characterized by an extensive soil cover. Visits will be made to :

- Paleozoic polymetallic massive sulphide prospects near Nantes and St Brieuc ;
- A gold shear zone-controlled stockwork near Angers ;
- Porphyry-type W-Sn-Mo-Ag-As mineralization near Nantes ;
- Stibnite veins discovered under a transported overburden near Nantes.

SALSIGNE GOLD MINE AND "LES MALINES" Pb-Zn MINE (South Massif Central).

B2 : April 26-29

M. BONNEMAISON, F. TOLLON, Ph. LAGNY

The Salsigne mine which has produced 80 tons of gold is located in the Cambrian volcano-sedimentary formations in the south of the Montagne Noire. Underground and surface visit will permit to observe the various types of mineralization : Sedex-type sulfo-arsenide beds, disseminated gold in quartzite sandstones and late-formed vein-type concentrations. Available geochemical data will be discussed.

The "Les Malines" deposit has produced so far 800,000 t of metals. It is a Cambrian calcareous paleorelief overlain by transgressive Trias. The Pb-Zn concentrations are a good illustration of mineralized paleokarst infilling.

This field trip is also an opportunity to make an historical tour to the city of Carcassonne and its famous medieval walls (12 th century).

PERI-DIAPIRIC TYPES Pb-Zn DEPOSITS IN NORTHERN TUNISIA.

F2 : April 26-30

J.J. ORGEVAL, A. GUEDRIA

This trip will show up the approach which led to the discovery of the Bou Grine Zn-Pb deposit where exploration geochemistry played a very important role. Emphasis will be placed on the specific problems arising when prospecting in semi-arid environments where calcretes and wind-blown material severely subdue the geochemical response.

In addition to the surface and underground visit to the Bou Grine deposit, a visit will be made to the currently mined Bou Jaber and Fedj el Adoum Zn, Pb, Ba, and F mines.

A sight-seeing tour of Carthage and of the Dougga Roman ruins is also included.

RECEPTIONS – VISITES

Soirée "Vins et Fromages de France" - 23 avril (de 18:30 à 22:00).

Organisée au restaurant du BRGM. elle sera l'occasion de découvrir les alliances privilégiées des fromages et des vins de quelques régions de France.

Soirée de gala au château de Cheverny - 25 avril.

Cheverny est situé à 50 km au sud d'Orléans. Les convives y seront accueillis, selon la tradition, au son des cors de chasse ; ils visiteront les intérieurs de ce logis seigneurial du 17e siècle, réputé pour son ameublement d'époque. La gastronomie française sera à l'honneur au cours du dîner dansant, servi aux chandelles.

Le rendez-vous pour le départ en car est fixé dans le hall de chaque hôtel entre 18:00 et 18:15.

Visites des services spécialisés du BRGM

Des visites des laboratoires, de l'atelier de télédétection et du département minéralurgie se dérouleront parallèlement aux sessions techniques. D'autres contacts avec des ingénieurs BRGM pourront être organisés à la demande, en s'adressant à l'Accueil du Congrès.

Programme de visites pour les personnes accompagnantes.

- Parc floral d'Orléans La Source : 23 avril après-midi.
- Visite des châteaux de Chambord et de Blois : 24 avril.
- Visite d'Orléans : 25 avril matinée.

SOCIAL PROGRAM

Wine and cheese reception - April 23 (from 18:30 to 22:00).

Held at the BRGM restaurant, Orléans, this reception is an unique opportunity to discover the "priviledged blending" of cheese and wines from a few regions of France.

Gala evening at the Château of Cheverny - April 25.

Cheverny is located about 50 km to the south of Orléans. The guests will be greeted with the traditional sound of the hunting horns. They will be invited to visit this 17 th century style seigniorial château and its famous genuine antique furniture. A cabaret dinner featuring the French gastronomy will be served by the candlelight.

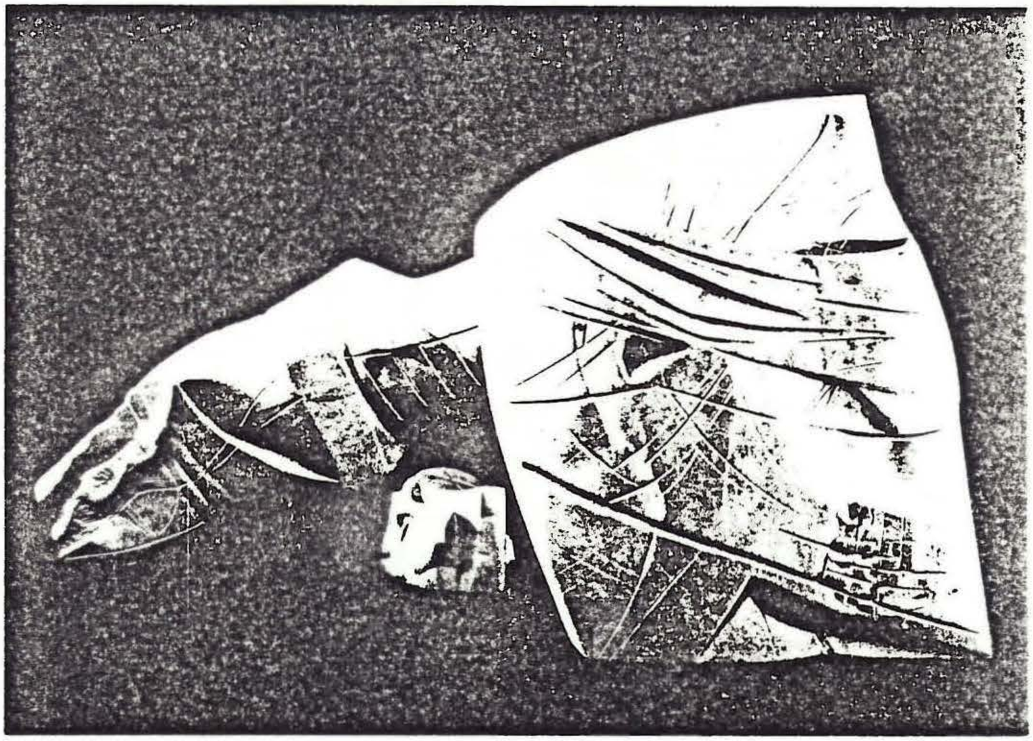
The meeting place prior to bus transport is fixed in the hall of each hotel between 18:00 and 18:15.

Visits to BRGM specialized services.

Visits to laboratories, remote sensing section and Ore Processing Department will take place simultaneously with the technical sessions. On request, other meetings with the BRGM technicians may be organized by contacting the Symposium reception desk.

Program for accompanying persons.

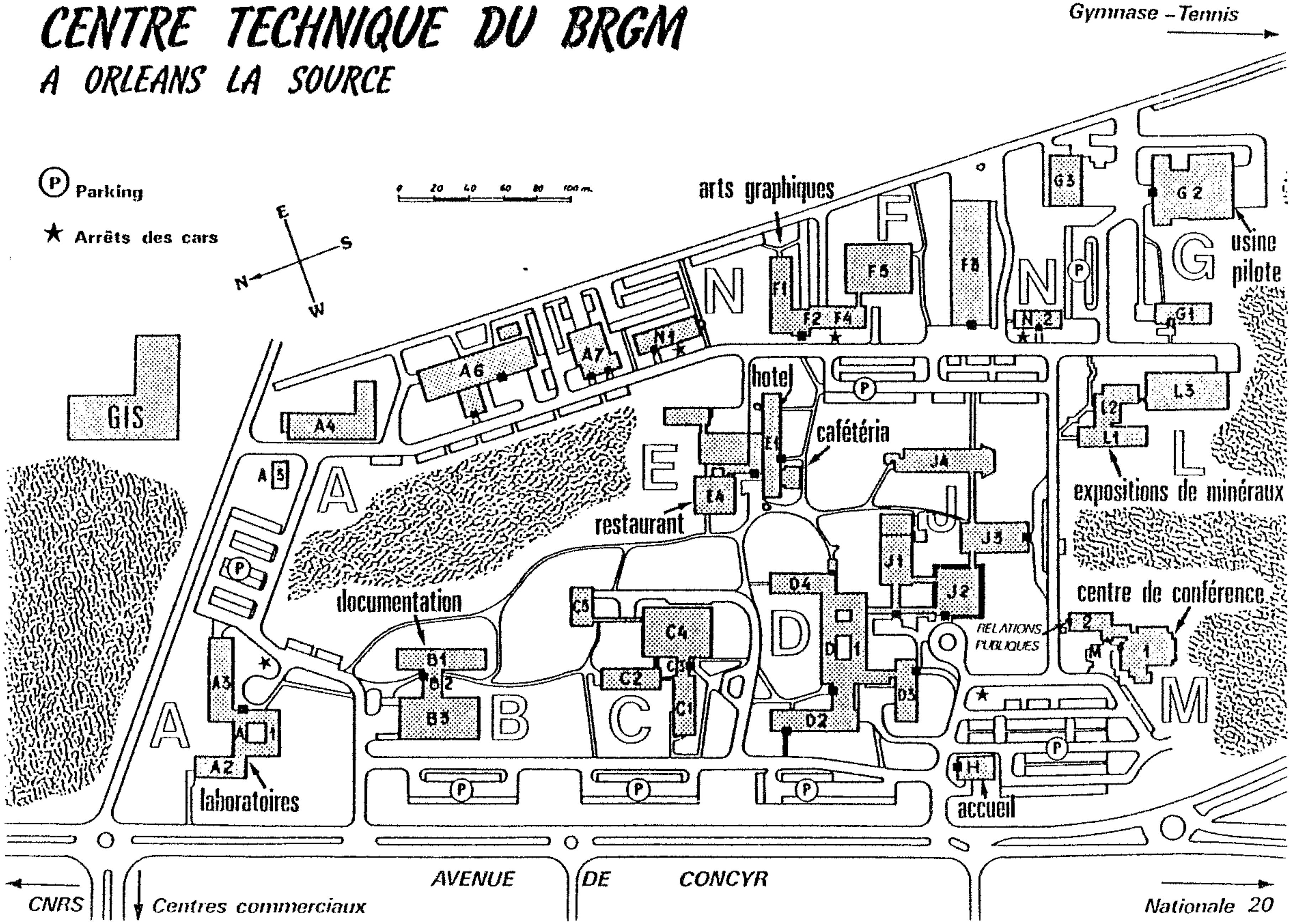
- Orléans-La-Source floral park : April 23 p.m.
- Visit to the Chambord and Blois Châteaux : April 24.
- Guided tour of Orléans : April 25 a.m.



Une autre sensibilité pour mettre en valeur la matière minérale ...

l'ARCHE, exposée dans le hall de la salle Gérard Philipe est une oeuvre du peintre-sculpteur orléanais Bernard FOUCHER.

CENTRE TECHNIQUE DU BRGM
A ORLEANS LA SOURCE



PROGRAMME TECHNIQUE
TECHNICAL PROGRAM

Ateliers
Workshops

Mercredi 22 Avril 1987

W1 : Comportement supergène de l'or : approche thermodynamique (Bâtiment D1).
Supergene behaviour of gold : thermodynamic approach.

Chaiman : **Y. TARDY**

W2 : Traitement de données. (bâtiment L1)
Data processing.

Co-chairmen : **R. GARRETT - P. LEYMARIE**

W4 : Prospection géochimique en milieu latérique (semi-aride à humide). (Auditorium M1).
Geochemical exploration in lateritic environment (semi-arid to humid).

Co-chairmen : **G.H.W. FRIEDRICH - D. NAHON - R.E. SMITH**

W5 : Sélection d'anomalies (Bâtiment C4).
Anomaly selection criteria.

Co-chairmen : **J.A. PLANT - M.A. CHAFFEE**

W8 : Cartographie géochimique internationale (Bâtiment J2).
International Geochemical Mapping.

Co-chairmen : **A. BJORKLUND - A.G. DARNLEY - P. KOVAL**

W9 : Techniques analytiques (Bâtiment A8)
Analytical techniques.

Co-chairmen : **M. BORSIER - I. BRENNER**

Présentations orales
Oral presentations

Jeudi 23 Avril 1987

OUVERTURES
OPENING CEREMONIES

9:30 : M. ALLEGRE - Directeur général du BRGM

9:40 : S.J. HOFFMAN - Vice-Président AEG

9:50 : P. KOVAL - Secrétaire IAGC, groupe de travail : Prospection géochimique

10:00 : E. WILHELM - Cochairman du Colloque

10:15 : Pause café - Break

Thème 1 : APPROCHES COMBINEES D'EXPLORATION
Topic 1 : INTEGRATED EXPLORATION TECHNIQUES

SESSION 1 : Chairmen : **L.K. KAURANNE - A. PAPON**

10:45 : **S.J. SUTLEY, R.M. O'LEARY, R.J. GOLDFARB**
A comparison of geochemical exploration techniques and sample media within accretionary continental margins.

11:05 : **B. COSTE, J. EKO-NDONG et D. BONNEFOY ;**
Traitement multisources : application aux données de l'inventaire minier transgabonais.

11:25 : **N.I. BOEV, S.A. VOLOD'KO, L.S. GALETSKY, A.I. ZARITSKY and E.P. ZAKHAROV ;**
A complex of geochemical and geophysical methods for concealed deposits prospecting and exploration.

11:45 : **C. ROQUIN, T. DANDJINOU, Ph. FREYSSINET et J.C. PION ;**
Spot images and geochemical prospecting of lateritic covers in south Mali.

12:05 : **D. BONNEFOY, M. JEBRAK, M.C. ROUSSET, H. ZEEGERS ;**
SERGE : un système expert en reconnaissance d'anomalies géochimiques.

12:30 : Repas - Lunch.

Thème 2 : PROSPECTION OR
Topic 2 : Exploration For Gold

SESSION 2 : Chairmen : **E. BURENKOV - O. WARIN**

14:30 : **O. WARIN** ; - Introduction du thème - keynote paper

14:50 : **P. TRUDEL, Y. METHOT et G. PERRAULT** ;
Géochimie de la minéralisation aurifère à la mine Eldrich, région de Rouyn-Noranda, Québec, Canada.

15:10 : **J. JANATKA and P. MORAVEK** ;
Geochemical exploration of the Célina Mokrsko gold district in the Jilove Belt, Bohemian massif, Czechoslovakia.

15:30 : **G. RECOCHE, F. COTTARD, Y. DESCHAMPS, Y. EL SAMANI and L. VIALLEFOND** ;
Geochemical signature of gold-bearing silica-barite formations in the Ariab district, Red Sea Hills, Sudan.

15:50 : Pause café - Break.

SESSION 3 : Chairmen : **J. ATKINSON, J.Cl. SAMAMA**

16:15 : **S.I. DAY and W.K. FLETCHER** ;
Effects of valley and local channel morphology on the distribution of gold in stream-sediments.

16:35 : **J.W. Mc CONNELL and P.H. DAVENPORT** ;
Gold and associated elements in lake sediments : their application to gold exploration.

16:55 : **M. IKRAMUDDIN** ;
The use of Tl/Eu ratios in precious metal exploration.

17:15 : Fin - Close

Vendredi 24 Avril 1987

Thème 3 : EXPLORATION GEOCHIMIQUE EN MILIEU TROPICAL
Topic 3 : GEOCHEMICAL EXPLORATION IN TROPICAL TERRAINS

SESSION 4 : Chairmen : **C. KASSA MOMBO, J. TRICHET**

8:30 : **H. ZEEGERS** : Introduction du thème - Keynote paper

8:50 : **I. SALPETEUR and H. SABIR**
Gold prospecting in the central pediplain of the Precambrian shield, Kingdom of Saudi Arabia.

9:10 : **A. GUEDRIA, I. TRICHET and E. WILHELM ;**
Influence of calcrete formation on Pb-Zn anomalies in soils of the Bou Grine area (Tunisia). Relevance to geochemical prospection.

9:30 :**B. MURRELL ;**
Dispersion of metals from the Edwards Creek gossan, Arunta complex (arid-zone) central Australia.

9:50 : **J.C. PARISOT, F. SOUBIES, P. AUDRY and F. ESPOURTEILLE ;**
Some implication of the lateritic weathering on the geochemical prospecting. Two Brazilian examples.

10:15 : Pause café - Break.

SESSION 5 : Chairmen : **D. APPLETON - H. DE LA ROCHE**

10:45 : **C.R.M. BUTT and H. ZEEGERS ;**
Geochemical Exploration models in tropical terrains.

11:05 : **Ph. FREYSSINET, A. EDIMO, P. LECOMTE and J. VAIRON ;**
Geochemical dispersion of gold and associated trace elements in a lateritic profile in eastern Cameroon.

11:25 : **R.E. SMITH, R.D. BIRRELL and J. BRIGDEN ;**
The implication to exploration of chalcophile corridors in the Archaean Yilgarn Block, Western Australia, as revealed by laterite geochemistry.

11:45 : **P. LECOMTE and F. COLIN ;**
Gold dispersion and size fraction distribution in a tropical rain forest weathering profile at Dondo-Mobi, Gabon.

12:05 : **P. TAUFEN and M.L. MARCHETTO ;**
Tropical weathering control of Ni, Cu, Co and PGE distribution at the O'TOOLE deposit, Minas Gerais, Brazil.

12:30 : Repas - Lunch.

Thème 4 : L'OR EN MILIEU LATERITIQUE
Topic 4 : GOLD IN LATERITIC ENVIRONMENT

SESSION 6 : Chairmen : **C.R.M. BUTT - F. MRNA**

14:30 : **A. DOMMANGET, H. TRAORE and H. ZEEGERS ;**
Discovery of the Loulo gold deposit (Mali).

14:50 : **T. DAVIES, G. FRIEDRICH and A. WIECHOWSKI ;**
Geochemistry and mineralogy of laterites in the Sula Mountains greenstone belt, Lake Sonfon gold district. Sierra Leone.

15:10 : **A.J. EGGO and M.G. DOEPEL ;**
Geochemical patterns associated with alterations at the Connemarra and Kathleen Au deposits, Western Australia.

15:30 : **G. TAYLOR, B. COSTE, A. LAMBERT and H. ZEEGERS ;**
Geochemical signature (bedrock and saprolite) of gold mineralization and associated hydrothermal alteration at Dorlin, French Guyana.

15:50 : Pause café - Break.

Thème 5 : PROSPECTION BIOGEOCHIMIQUE DES METAUX PRECIEUX
Topic 5 : BIOGEOCHEMICAL EXPLORATION FOR PRECIOUS METALS

SESSION 7 : Chairmen : **J. BERGSTROM - J. GONI**

16:15 : **F.D. BUSCHE ;**
Using plants as an exploration tool for gold.

16:35 : **J.D. STEDNICK and W.C. RIESE ;**
Temporal variation and lithologic dependence of metal concentrations in biogeochemical samples.

16:55 : **C.E. DUNN and G.E.M. HALL ;**
Platinum-group metals in common plants of northern forests : developments in analytical methods and the application of biogeochemistry to exploration strategies.

17:15 : Fin - Close

Samedi 25 Avril 1987

Thème 6 : PROSPECTION SOUS-RECOUVREMENT ALLOCHTONE
Topic 6 : EXPLORATION IN TRANSPORTED OVERBURDEN

SESSION 8 : Chairmen : **I. BARAKSO - M. LELEU**

8:30 : **J.C. SAMAMA, J.J. ROYER et C. N'GANZI ;**
Utilisation du facteur d'adsorption en prospection géochimique : Exemple de l'Uranium dans les sédiments de ruisseau.

8:50 : **B. GAUTHIER and J.R. DISNAR ;**
Contribution of organic geochemistry of the regional exploration of sulphide mineralization.

9:10 : **A.D. LOBANOVA ;**
On the relationship between primary and secondary geochemical fields in deep-seated deposits.

9:30 : **Cl. GRANIER, J. HARTLEY, J.C. MICHAUD et G. TROLY ;**
Découverte d'extensions du gisement polymétallique de Thalanga sous couverture puissante, par application de la géochimie tridimensionnelle Pb, Zn, Cu, Ag (Queensland - Australie).

9:50 : **P. LECHLER ;**
Recognition of hydrothermal alteration patterns in soils and bedrock using anion geochemistry.

10:15 : Pause café - Break.

Thème 7 : DEVELOPPEMENTS ANALYTIQUES ET TECHNIQUES ISOTOPIQUES
Topic 7 : ANALYTICAL DEVELOPMENTS AND ISOTOPIC TECHNIQUES

SESSION 9 : Chairmen : **B. BOLVIKEN - R. VAQUER**

10:45 : **E. MARCOUX, F. COTTARD, Y. EL SAMANI, G. RECOCHE, J.Y. CALVEZ and Y. DESCHAMPS ;**
Isotope signatures (Pb-Sr) of polymetallic mineralization in the Ariab district (Red Sea Hills, northeast Sudan).

11:05 : **B.L. GULSON, R.R. LARGE and P. PORRITT ;**
Gold exploration at Tennant Creek, Australia, using lead isotopes.

11:25 : **E.L. HOFFMAN ;**
Instrumental neutron activation analysis (INAA) as an analytical technique for gold and platinum-group Element exploration.

11:45 : **H. MARTIN, F. SONDAG et J.N. BOLLE ;**
Utilisation des méthodes d'extractions chimiques sélectives pour la prospection géochimique en milieu latéritique. AEG.

12:30 : Repas - Lunch.

Thème 8 : TRAITEMENT DES DONNEES ET MODELISATION
Topic 8 : DATA PROCESSING AND MODELING

SESSION 10 : Chairmen :**Cl. LEPELTIER - R. SIEGEL**

14:30 : **R.G. GARRETT ;**
The Chi-square Plot : a tool for multivariate outlier recognition.

14:50 : **C.R. STANLEY and J. SINCLAIR ;**
Comparison of probability plots and the gap statistic in the selection of thresholds for exploration geochemistry data.

15:10 : **P. LEYMARIE ;**
Quelques utilisations possibles de la géochimie en roches pour la prospection des gisements d'Uranium dans les leucogranites.

15:30 : **L. SANDJIVY ;**
L'analyse géostatistique des données de prospection géochimique.

15:50 : Pause café - Break.

SESSION 11 : Chairmen : **A. SINCLAIR - R. MAZZUCHELLI**

16:15 : **F.G. MUGE, A.J. SOUSA, M. VAIRINHO et V. OLIVEIRA ;**
Contribution pour l'étude statistique et structurale de données géochimiques de la région de Coroada (Moura-Portugal).

16:35 : **K.H. ESBENSEN and A. STEENFELT ;**
Geochemical prospecting in complex sample media. Multivariate data analysis of indirect observations.

16:55 : **J. BARBIER ;**
Intérêt de l'évaluation quantitative des anomalies géochimiques en sol, relevées en prospection détaillée.

17:15 : Fin - Close.

Dimanche 26 Avril 1987

Thème 9 : GEOCHIMIE EN ROCHES
Topic 9 : ROCK GEOCHEMISTRY

SESSION 12 : Chairmen : **J. BARBIER - G. VALIQUETTE**

8:50 : **P.V. KOVAL, A. GOTOVSUREN, S. ARIUNBILEG and J.I. LIBATOROV ;**
On prospecting of porphyry copper mineralization in intra-continental mobile zones (Mongol - Okhotsk - belt, M.P.R.)

9:10 : **R. LAHTINEN ;**
Application of the zonality of ore associated elements to exploration for volcanogenic massive sulphide deposits : a case study of the Pukkiharjn Zn-Cu prospect, Kuopio, Finland.

9:30 : **J.J. BARAKSO ;**
The applications of enlarged primary haloes by heavy mineral concentrations of trace elements.

9:50 : **E.K. BURENKOV, G.N. MUKHITDINOV, J.N. REZNIKOV ;**
Procedure for evaluation of lithochemical anomalies in large scale mineral exploration.

10:15 : Pause café - Break.

SYNTHESE DES ATELIERS
WORKSHOP REPORTS

SESSION 13 : Chairmen : **P. TRUDEL - F. MUGE**

10:45 : **W1, W2, W4, W5, W7.**

SESSION 14 : Chairmen : **A. BJORKLUND - A.G. DARNLEY - P. KOVAL**

11:30 : Cartographie géochimique internationale (W8).
International geochemical mapping.

12:20 : **Cloture - Closing ceremonies.**
Chairmen : **E. WILHELM - H. ZEEGERS.**

Présentation des posters
Poster presentations

Thème 1 : APPROCHES COMBINEES D'EXPLORATION
Topic 1 : INTEGRATED EXPLORATION TECHNIQUES

P.J. ROGERS, G.F. BONHAM-CARTER and D.J. ELLWOOD ;

Integrated mineral exploration using catchment basin analysis, Cobequid Highlands, Nova Scotia.

F.R. SIEGEL and R. JOWETT ;

Geochemistry and V.L.F.-EM in sphalerite find near St-Jovite, Canada.

J.L. TURIEL, M.E. DURAN, J. SAAVEDRA and M. VILADEVALL ;

Comparison between analytical and mineralometric methods on regional exploration of scheelite mineralization in western Zamora (Spain).

C. WATTS and J.R. HASSEMER ;

Geochemical signatures of possible deep-seated ore deposits in Tertiary volcanic centers, Arizona and New Mexico.

Thème 2 : PROSPECTION OR
Topic 2 : EXPLORATION FOR GOLD

J.D. APPLETON, J. CLAROS and W. RODRIGUEZ ;

Lithogeochemical and mineralogical indicators of Andean precious metal and polymetallic vein mineralization .

M. BONNEMAISON, D. BONNEFOY, C. BRAUX ;

Signatures géochimiques des shear-zones aurifères.

M.A. CHAFFEE and R.H. HILL ;

Soil geochemistry of Mother lode-type gold deposits in the Hodson mining district, central California, USA.

P. HUBERT, C. BENY and J.Cl TOURAY ;

Geochemistry of fluid inclusions in gold-bearing shear-zones : the Cros-Gallet deposit (France) and the Sanoukou prospect (Mali).

J. IGLESIAS, J. LOREDO and F. RUIZ ;

Mineral exploration for gold bearing horizons in the central-western zone of Asturias (Spain).

O. TOVERUD ;

Geochemical prospecting for gold in the county of Jamtland, upper central Sweden.

R. VASQUEZ-LOPEZ, Y. LEFUR, H. CHEVANCE, F. BELLIVIER, R. BROSSET, L. CALLIER, M. KERJEAN ;

La recherche de l'or primaire dans le massif Armoricain (France) : approches géochimiques et minéralogiques combinées.

Thème 4 : L'OR EN MILIEU LATERITIQUE
Topic 4 : GOLD IN LATERITIC ENVIRONMENT

Ph. FREYSSINET and H. ZEEGERS ;

Morphoscopy and geochemistry of gold in a lateritic profile at Kangaba (southern Mali).

J. RIDGWAY and P.N. DUNKLEY ;

Tempor l variations in the trace element content of stream-sediments from the seasonally wet-dry tropics.

Thème 5 : PROSPECTION BIOGEOCHIMIQUE DES METAUX PRECIEUX
Topic 5 : BIOGEOCHEMICAL EXPLORATION FOR PRECIOUS METALS

E. PULKKINEN, M.L. RAISANEN and L. UKONMAANAHO ;

Geobotanical and biogeochemical exploration for gold in the Sattasuaara volcanic complex finnish Lapland.

Thème 6 : PROSPECTION SOUS RECOUVREMENT ALLOCHTONE
Topic 6 : EXPLORATION IN TRANSPORTED OVERBURDEN

A. ALLON, R. BIRON, Y. LEFUR et R. VASQUEZ-LOPEZ ;

Un résultat remarquable de la prospection géochimique sous recouvrement de limons : la découverte du gisement d'antimoine des Brouzils.

P. DEGRANGES, J.Cl. BAUBRON, D. DEFOIX, T.K. BALL and R.D. NICHOLSON ;

Ajustment of soil gas analysis for geochemical prospecting.

L. LAVILLE-TIMSIT and E. WILHELM ;

An attempt for selectively using the chemical dispersion of metals to search for hidden deposits.

S.L. SHVARTSEV, N.M. RASSKAZOV, U.G. KOPYLOVA and E.M. DUTOVA ;

Hydrogeochemical criteria of ore deposit exploration in siberian conditions.

J.F. SUREAU, J. LETALENET and A. COUMOUL ;

Mercury in soil : a tool for exploration for hidden Pb-Zn ore deposit in sedimentary cover formation. Application in the "La Croix de Pallières" district (Gard - France).

G. VERRAES ;

Exemple d'utilisation combinée de la mercurométrie et de la géochimie en roches pour la détection de colonnes minéralisées du filon à Zn-Pb de St-Salvy (Tarn), partiellement recouvert par des dépôts tertiaires.

R. WATTERS ;

Importance of understanding geochemical processes vis-à-vis environmental consequences.

Thème 7 : DEVELOPPEMENTS ANALYTIQUES ET TECHNIQUES ISOTOPIQUES
Topic 7 : ANALYTICAL DEVELOPMENTS AND ISOTOPIC TECHNIQUES

M. BORSIER et A. BATEL ;

L'analyse des platinoïdes en prospection géochimique : présent et futur.

I.B. BRENNER, M. BEYTH and L. HALICZ ;

Application of multi-element inductively coupled plasma atomic emission spectrometry (ICP-AES) in hydrogeochemical mineral exploration.

L. GULSON, A. MEIER, E. CHURCH and J. MIZON ;

A comparison of lead isotopic measurements on exploration type samples using ICP and thermal ionisation mass spectrometry.

Thème 8 : TRAITEMENT DES DONNEES ET MODELISATION
Topic 8 : DATA PROCESSING AND MODELING

H. KURZL ;

Data analysis and geochemical mapping for the regional stream-sediment survey of Austria.

J.Cl. LASSERRE, J. TESTARD et B. COSTE ;

Le traitement multi-données : application à la sélection des zones à forte potentialité aurifère dans le sud de la Guyane Française.

H. WACKERNAGEL et C. BUTENUTH ;

Deux méthodes géostatistiques pour l'interprétation et la détection d'anomalies géochimiques.

Thème 9 : GEOCHIMIE EN ROCHES
Topic 9 : ROCK GEOCHEMISTRY

J.M. CARMONA and M. VILADEVALL ;

Evolution of the Catalonian coastal Ranges from Caradocian to Silurian : Interaction between metallogenic processes and physico-chemical environment.

A. ERLER ;

Geochemical character of the hydrothermal alteration zones around the Madenköysiirt massive sulfide deposit and its implications for geochemical exploration.

Thème 10 : PROSPECTION GEOCHIMIQUE REGIONALE
Topic 10 : REGIONAL GEOCHEMICAL EXPLORATION

F. BARTHELEMY, M. KASSA MOMBO et J.F. LABBE ;

Inventaire minier transgabonais : Campagnes géochimiques régionales et détaillées 1979-1986. Acquisition des données sur le terrain.

B. BOLVIKEN, J. BERGSTROM, A. BJORKLUND, M. KONTIO, P. LEHMUSPELTO, T. LINDHOLM, J. MAGNUSSON, R.T. OTTESEN, A. STEENFELT, T. VOLDEN ;

Geochemical mapping in the nordkalott project, northern Fennoscandia.

A. DJUNUDDIN, H. SUMARTONO ;

Review of Sawang-Labuhan Haji geochemical follow-up, northern Sumatra Indonesia.

N. GUSTAVSSON, T. KOLJONEN, P. NORAS and H. TANSKANEN ;

Geochemical atlas of Finland.

G. HAUSBERGER, O. SCHERMANN, E. SCHROLL and F. THALMANN ;

Geochemical prospection activity in Austria by the Geological Survey and Voest-Alpine AG.

J.L. MARRONCLE, J.R. LE CHAPELAIN, J.J. PERICHAUD et J.Cl. PREVOST ;

Synthèse géologique et métallogénique du faisceau de Pontgibaud et de ses marges (Massif Central français).

E. WILHELM, L. LAVILLE-TIMSIT, J.J. PERICHAUD, L. VIALLEFOND ;

Le programme décennal d'inventaire des ressources minérales de la France.

J. KABORE, G. MATHEZ, F. OUEDRAOGO ;

Prospection géochimique dans le centre et le nord-ouest du Burkina Faso.

Thème 11 : TECHNIQUES SPECIFIQUES D'ECHANTILLONNAGE ET DE PREPARATION DES PRELEVEMENTS
Topic 11 : SPECIFIC SAMPLING AND SAMPLE PREPARATION PROCEDURE

D. ARTIGNAN ;

Diagnostic précoce de la signification gitologique des anomalies stratégiques par analyse ICP des minéraux lourds.

W.B. COKER, D.J. ROBERTSON and R.J. SNOW ;

Till geochemistry at the great Gull scheelite prospects, New Foundland, Canada. A case history in orientation and discovery.

B. GUILLET, E. JEANROY et C. ROUGIER ;

Effet du cycle biogéochimique sur la distribution des éléments traces (Cu, Pb, Zn, Co, Ni, Ca) dans les sols de l'étage montagnard vosgien.

R. OTTESEN ;

Overbank deposits as a sampling medium in geochemical mapping.

A. SADEIGH and K.F. STEELE ;

Use of stream sediment elemental enrichment factors in geochemical exploration for Uranium and carbonatite deposits, Arkansas - USA.

R. SALMINEN, P. LESTINEN and A. HARTIKAINEN ;

Enrichment of arsenic and sulphur in the finest fractions of crushed rock samples ; an experimental study.

Thème 1 : APPROCHES COMBINEES D'EXPLORATION
Topic 1 : INTEGRATED EXPLORATION TECHNIQUES

A complex of geochemical and geophysical methods for concealed deposits prospecting and exploration.

Concealed deposits including those buried under the allochthonous cover are the main reserve for mineral resources growth. A complex of geochemical and geophysical methods depending on the geological task, landscape, geological and metallogenical features of the area is successfully used in the USSR.

N.I. Boev
S.A. Volod'ko
L.S. Galetsky
A.I. Zaritsky
E.P. Zakharov

I. In order to choose geochemical and geophysical methods for prospecting at first the area is mapped on its natural conditions. The classification of the latter is based on the thickness of the sedimentary cover, presence and pattern of chemically active and permeable layers ; predominant direction of ground water migration ; depth to the capillary fringe of the first water-bearing horizon and that of the common vegetation ; types of the weathering crust of the basement ; evidence of pneumatolitic, hydrothermal and other superimposed processes accompanied by gaseous fluids ; soil complexes ; technogenic features and (if necessary) other factors. When geophysical methods are chosen, the main and trace-elemental composition and differentiation of the primary and secondary geochemical fields are taken into account as well as the needed detailing of the prospecting or exploration.

II. Regions promising for new deposits are recognized on the 1/500 000 - 1/200 000 scale by means of geophysical and spectrometric aerosurveys combined with geochemical sampling of alluvial and proluvial wastes, seismic profile shooting and selective aerial magnetic and gravimetric survey. The geochemical sampling includes two main types :

- sampling of crop, detrital clastic and clay-silt sediments of the constant and temporary streams ;
- sampling of water, bottom mud of the constant streams and vegetation on their flood plain boundaries, additional sampling of crop and detrital clastic (when the latter being present) within hydro -and mud-geochemistry anomalous area.

The smooth terrain is studied by profile and aerial atmogeochemical surveys.

III. Complex studies in promising regions on the 1/50 000 - 1/10 000 scale include prospecting for ore fields and deposits :

- geochemical surveys dealing with secondary haloes on the surface embrace sampling of soil, detrital rock wastes with the sampling of the bedrock at outcrops ;
- the same technique plus phitochemical survey ;
- complex of geochemical sampling of water, then - vegetation and soil ;
- the sampling of ground air, vegetation and soil ;
- borehole investigations including lithochemical, hydrochemical methods and studies of crop are successfully used with sampling of soil and air to study volatile elements of wide dispersion ;
- borehole studies covering lithochemical, hydrochemical techniques and crop studies of rocks are used for profiles crossing the geophysical anomalies in areas with no evidence of geochemical halos on the day surface.

New methods (soil geochemistry, in particular) and procedures of geochemical exploration have been developed and used in the USSR lately. They are based on studies of superimposed fluidal and "mechanical" halos and make it possible to obtain a two-fold labor productivity and even a greater one than their previous analogues. The efficiency of the new methods, with geophysical detailization particularly is several times higher. The detailization depends on type of geophysical and geochemical anomalies found in the areas and is based on the following methods :

- dielectric polarization and electromagnetic methods for chalcophile elements in haloes ;
- magnetic survey in case of siderophile elements ;
- gravimetric and electric resistance methods in case of high content of lithophile elements and distinct differentiation of the fields as to lithophilic and siderophilic elements ;

- piezoelectric, acoustimetric and microseismic methods for haloes of volatile elements of high dispersion with the content of other, chemical elements raising indistinctly.

The final task of complex prospecting is to evaluate the primary mineral and geochemical haloes zonality of ore fields and potential deposits, and to reveal the most common features of ore formation (at depth, if possible).

The complex interpretation of geochemical and geophysical data makes it possible to compile geological ore-forecasting maps.

IV. Explorative and evaluating geochemical and geophysical work on the scale of 1/10 000 - 1/2 000 is carried out primarely in parts of the geochemical halos characterized by the most distinct spatial productivity and zonality of ore and accompanied elements and then usually correspond to large and mean deposits.

At first lithochemical and mineral fields are mapped for surfaces and lower parts of the zones of the bedrock weathering crust and for chemically active layers of the sedimentary cover and for the upper part of ore-bearing rocks. The latter are studied for physical properties within an ore halo and in background fields.

Vertical and horizontal components of mineral, lithochemical and lithophysical zonality and the direction of the field center pitch are spatially studied. Boreholes reach the depth comparable with the halfwidth of the halo value.

The holes are to intersect lower ore-bearing parts of large ore cluster haloes if the polyelemental field productivity and spatial separation of the main chemical elements increase with depth.

Ores and various host rocks are studied for the chemical and physical composition of gas and liquid inclusions.

Explorative and evaluating work resulted in compiling a set of ore-forescasting geological maps, sections, then the conclusion is drawn on the economic significance of the ore occurrences.

The proposed systematic approach to choose proper complex of geochemical and geophysical methods enables to reveal mineral deposits to depth of tens and hundreds of metres.

SERGE : un système expert en reconnaissance d'anomalies géochimiques.

D. Bonnefoy
M. Jebrak
M.C. Rousset
H. Zeegers

La prospection géochimique n'a connu son développement récent que grâce aux progrès importants réalisés en matière d'analyse mutiélémentaire et de traitement informatique. Ainsi, en France, ont pu être menées l'analyse et l'interprétation des résultats pour plus de 250 000 échantillons. La nécessité d'une sélection des cibles minières à un stade de plus en plus précoce a mis en relief le besoin de procédures fiables de sélection des anomalies géochimiques prenant en compte des facteurs non numériques très variés : type de prélèvement, contexte morpho-climatique et géologique, contexte anthropogénique, etc.

C'est cette analyse que réalise SERGE, Système Expert en Reconnaissance Géochimique mis au point par le Bureau de recherches géologiques et minières et le Laboratoire de Recherche en Informatique de l'Université de Paris Sud. SERGE est, en effet, capable d'imiter le raisonnement d'un expert géochimiste dans le classement d'anomalies géochimiques multi-élémentaires.

SERGE est composé de trois parties distinctes, une base de connaissances, un moteur d'inférence, et des interfaces.

La base de connaissance contient l'expertise. Celle-ci est exprimée sous la forme de règles de production du type Si X, alors Y ; par exemple : si les teneurs en Cr sont élevées, alors il y a un risque de pollution. Cette formulation est proche du langage naturel et pêut être aisément modifiée ou complétée. SERGE comprend actuellement une base de connaissance d'environ 150 règles applicables aux anomalies à métaux de base en Bretagne. Ces règles concernent principalement la morphologie de l'anomalie, le type de prélèvement, le contraste, les pollutions, le paysage, les éléments accompagnateurs valorisants ou pénalisants.

Le moteur d'inférence gère l'ensemble de la connaissance. Il s'agit d'un moteur fonctionnant en chaînage avant et en chaînage arrière, sans utilisation de coefficient de probabilité. Il explique son raisonnement, soit au cours du dialogue avec l'utilisateur en explicitant les problèmes qu'il tente de résoudre, soit à l'issue de son diagnostic en justifiant sa démarche.

Les interfaces permettent d'alimenter le système. Deux types d'alimentation peuvent être distingués (1) une alimentation manuelle, où l'utilisateur répond aux questions de SERGE ; (2) une alimentation semi-automatique où SERGE va chercher au sein de fichiers d'images. les données qui lui sont nécessaires, comme le contraste géochimique, le contexte géologique, le type d'anomalie ...

Des tests montrent que SERGE présente des performances intermédiaires entre un expert de haut-niveau et des géochimistes avec cependant un comportement légèrement optimiste.

Ainsi, contrairement à PROSPECTOR où l'ensemble des spécialistes contribuant à la recherche minière tentait d'être remplacé par un système-expert, SERGE ne s'intéresse qu'à une classe bien particulière de problèmes, celle du classement des anomalies, à l'issu d'une chaîne de traitement algorithmique. Ce n'est que dans des cadres très étroits que ce type de logiciels peut apporter réellement un appui à l'interprétation des problèmes géologiques.

Traitement multisources : application aux données de l'inventaire minier transgabonais.

B. Coste
J. Eko-Ndong
D. Bonnefoy

Dans le cadre de l'Inventaire minier entrepris par le gouvernement du Gabon, le BRGM, depuis 1981, a couvert en prospection régionale plus de 40 000km². L'approche mise en oeuvre comporte un lever géologique, une prospection directe des indices minéralisés, une prospection géochimique par prélèvements de stream sediments (analysés ensuite pour 34 éléments) et une prospection à la batée avec détermination minéralogique (une vingtaine de minéraux) des concentrés. Simultanément, l'ensemble du territoire Gabonais faisait l'objet d'une couverture géophysique aéroportée, incluant spectrométrie et magnétisme, ainsi que d'un lever radar.

A la fin de chaque campagne de terrain, un processus classique de traitement et d'interprétation des données géochimiques conduit à la sélection d'anomalies qui sont retenues ou non pour des travaux ultérieurs. Cette interprétation s'appuie bien évidemment sur l'information géologique et gîtologique disponible.

Très vite, les données géochimiques se sont avérées très utiles, non seulement pour la recherche de minéralisations, mais aussi pour compléter l'information géologique souvent lacunaire étant donné la rareté et la mauvaise qualité des affleurements. Ceci nous a conduit à concevoir un nouvel échelon dans l'interprétation des résultats géochimiques, à savoir la réalisation tous les 2 à 3 ans d'une synthèse à caractère régional.

A une telle échelle, il est opportun voire indispensable de prendre en compte l'ensemble des données disponibles sur les régions travaillées : le principe des synthèses multi-méthodes a donc été retenu.

Techniquement, de telles synthèses nécessitent en préambule une mise à compatibilité des différentes variables traités, ce qui est réalisé aisément grâce au logiciel SYNERGIE développé au BRGM. Dans la pratique, cette harmonisation consiste à projeter toutes les informations aux noeuds d'une même grille dont les cellules élémentaires (pixels) ont 500 m de côté.

Ont ainsi été traitées les données issues des prospections géochimiques et alluvionnaires, de la campagne de géophysique aéroportée, du lever radar et de la photogéologie (par digitalisation des images interprétées).

L'espace multi-descripteur correspondant nécessite une condensation par sélection des variables significatives et non-redondantes, qui peut s'effectuer par voie graphique avec affichage interactif sur écran coueur ou par le biais d'un traitement statistique : analyse factorielle des correspondances, classification, etc.

Pour l'exemple d'application présenté (degré carré de Booué) d'excellents résultats ont été obtenus pour la caractérisation fine d'un environnement géologique peu contrasté et très métamorphisé, en valorisant la complémentarité des informations utilisées. Ainsi, les données géochimiques donnent accés à la lithologie initiale, les minéraux lourds précisent l'intensité du métamorphisme tandis que la géophysique aéroportée et le lever radar permettent de brosser les grands traits structuraux.

On campe ainsi une nouvelle scène géologique, sur laquelle les anomalies et indices repérés pourront être projetés pour mieux en apprécier l'intérêt.

L'interprétation de phénomènes très ponctuels, comme des anomalies géochimiques, passe donc par un retour à une échelle régionale, étape dont l'efficacité est renforcée par la prise en compte de la totalité de l'information disponible.

Integrated mineral exploration using catchment basin analysis, Cobequid Highlands, Nova Scotia.

P.J. Rogers
G.F. Bonham-Carter
D.J. Ellwood

A pilot study previously reported in Bonham-Carter et al. (in press) and Rogers et al. (1986) discussed the application of catchment basin analysis to the integration of surficial geochemistry with bedrock geology using image analysis. In this paper we report on an extension of this work to (a) cover a larger area, (b) further refine the method for characterizing geochemical background for the regional survey and (c) include a measure of variability based on field duplicates.

The Cobequid Highlands of northern Nova Scotia comprise an elongated area 160 km east-west by 50 km north-south, rising to a maximum of 350 m above sea level. A central core of Precambrian and Lower Paleozoic schists, gneisses, volcanics and sediments is intruded by numerous Devono-Carboniferous granitoids. The highlands are bounded to the south by the major Cobequid - Chedabucto Bay fault system and to the north by the Cumberland Basin. The flanking lowlands comprise Late Paleozoic to Mesozoic rocks. Known mineralization has been identified in various significant associations, including Cu-U sandstone-hosted deposits, fault-related Mn deposits, poorly understood vein deposits containing precious metals, and polymetallic vein deposits. Mapping at 1:50,000 scale has identified about 65 rock units. This bedrock map has been raster scanned and the resulting digital image is 3335 x 960 pixels (50 m/pixel).

A 1983 regional stream-sediment geochemical survey collected about 1500 -80 mesh samples, at an average density of 1 sample per 2.5 km^2. These samples were analyzed for Cu, Pb, Zn, Ag, Fe, Mn, Ni, Co, As, Hg, U and Mo in sediments , U, F and pH in surface waters. Field duplicates were collected at 1 site in 20. One of each duplicate pair was split to act as the analytical control.

Sample locations were plotted on a 1:50,000 scale base topographic map and catchment basins upstream from each site outlined by hand. The resulting map was also raster scanned to produce a second image in registration with the geological base. A computer file describing the geochemical composition of each sample and the geological composition (map units) of its associated catchment basin was created. Field sampling strategy included some nested basins, so samples are not necessarily geochemically or statistically indepedent from one another.

Coloured maps from an Applicon ink jet plotter using a percentile scale were made for each element. Each catchment basin was coloured according to the sample value, instead of using symbol plots or interpolation schemes which normally assume that the area of influence is centred on the sample location.

These plots reveal broad trends related to major structural features and stratigraphic units. The first three principal components of the logarithms of the element data (explaining 64 % of variance), plotted as factor scores with each factor as one of three primary colours, reveal a number of distinct geochemical provinces. These geochemical provinces are of distinct geological composition, and the plots provide a valuable summary of background geochemistry and its relationship to geology and structure.

The relationship between element concentration and its variance has been modelled using the field duplicates. This permits estimation of 95 % confidence limits for cutoff values between colour classes, for untransformed single element plots.

Regression analysis has been used to model background effects for each element using areal proportions of mapped units as independent variables. After removing background, residual maps enhance the definition of anomalous areas and aid in target selection for exploration. Tables showing average background response for each unit are produced.

Catchment basin plots not only provide an insight into the spatial variation of multi-element associations and their geological control, but also isolate potential exploration targets which can then be integrated with other data sources, such as remotely-sensed radar and airborne geophysics. The ultimate goal of this intregration study is to produce target area maps based on ore deposit models.

REFERENCES

BONHAM-CARTER, G.F., ROGERS P.J., and ELLWOOD D.J. (in press). Catchment basin analysis applied to surficial geochemical data, Cobequid Highlands, Nova Scotia. J. Geochem. Explor., V. 27.

ROGERS, P.J., BONHAM-CARTER, G.F. and ELLWOOD, D.J., 1986 - Anomaly enhancement by use of catchment basin analysis on surficial geochemical data from the Cobequid Highlands, Nova Scotia. In : Prospecting in Areas of Glaciated Terrain, IMM Symposium, Finland, September, 1986, p. 163-174.

Spot images and geochemical prospecting of lateritic covers in south Mali.

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In tropical areas, geological features of the bedrock are often concealed by an extensive lateritic mantle and its erosion products. The joined effects of deep lateritic weathering and erosion processes result in a great variety of materials exposed at the surface. Many recent studies have shown that efficiency of geochemical prospecting in such lateritic landscapes strongly depends on a good understanding of the nature and evolution of superficial formations.

On the geochemical prospect of Dagadamou in southern Mali, mapping of superficial lateritic formations is carried out using recent high resolution SPOT satellite images. An objective of this study is to compare the multispectral and geochemical signatures of lateritic covers.

The study area, in southern Mali, is located in the Kangaba district, between the Niger valley and the border with Guinea. Climate is of Sudanian type with two contrasted seasons. The mean rainfall in the humid season is about 1,250 mm. Savannah-type vegetation, is more developed along the drainage networks in the valleys and at the margin of plateaus.

The regional landform is characterized by high plateaus of ferruginous duricrust dissected by broad bottom-flat valleys. In the eastern part of the area, plateaus are higher and often limited by escarpments while they are more rounded in the western part. An overburden of fine sand and clay materials is accumulated in the valleys and the lowest parts of the plateaus. The basement rocks corresponding to the metamorphic volcano-sedimentary units of Birrimian âge (Precambrian C), are pratically never exposed at the surface.

During a detailed geochemical survey carried out over 25 km^2 in 1981 by the BRGM and DNGM, 1062 samples were collected on a regular 100 m x 200 m grid and analyzed by plasma emission spectrometry for 8 major oxides (SiO_2, Al_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2, MnO) and 26 trace elements (Ba, P, B, V, Cr, Co, Ni, Cu, Zn, As, Cr, Y, Sr, Zr, Li, Be, Cd, Nb, Ag, Sn, Sb, La, W, Pb, Bi). Samples were classified by field observations, according to the nature of the materials collected at each sampling site. The three main groups correspond to 479 samples of massive ferruginous duricrust, 278 samples of gravels, corresponding to loose fragments of the duricrust and 240 samples of sandy soils from the valleys.

SPOT satellite multispectral image of this area (scene 39-326), was acquired, at the end of the dry season, on 6 April 1986 at 11a.m. It is an oblique view, with 25° incidence, for the two spectral bands in the visible range, XS1 (0.5-0.59μm), XS2 (0.61-0.68μm) and the infrared band XS3 (0.79-0.89μm). The pixel size after standard geometric correction is 20 m x 20 m.

Both geochemical and spectrometric data were analyzed using statistical processing, graphical plotting and mapping. A subscene of 275 x 225 pixels was selected after rotation of SPOT image and superposed on the geochemical maps. Correlations between the two data sets werere also studied by picking out pixels or SPOT image corresponding to geochemical sampling and merging the two files.

The main geochemical differentiation factor, closely related to the nature of sampled materials, opposes silica to iron and aluminium contents. It can also be expressed as relative proportions of estimated minerals, quartz, kaolinite, goethite, hematite, gibbsite after normative calculation.

- Duricrust samples with high iron and aluminium contents are also enriched in trace elements, P, V, Cr, As, Mo, Nb and Cu, immobilized in the weathering profile with secondary oxyhydroxide minerals.

- Soils of flats, mainly composed of quartz and kaolinite, also concentrate heavy minerals characterized by high Zr, Y, Ti, Ce, B contents.

- Ferruginous gritty soils present a continuous range of intermediate composition between duricrusts and soil samples from flats.

On the geochemical maps the contrast between ferricrete plateaus and sandy soils of the flats is important The outline of plateaus is enhanced by a geochemical halo of higher zirconium and quartz contents, indicating detritic material accumulation at their periphery.

On SPOT images the main landscape features are easily identified by variation of reflectance in the three spectral bands XS1, XS2, XS3. Spectral signature of a pixel is characterized on color composite images by a combination of three primary colors.

Influence of vegetation, still important at this period of the year, is characterized by high reflectance values in infrared band XS3 and relatively low reflectance in the visible bands XS1 and XS2. An index of vegetation density is computed as : 100*(XS3-XS2)/(XS3+XS2). Vegetation is more abundant in the valleys and along the stream channels. On the plateaus, vegetation is frequently concentrated along several parallel lines, giving a hatching pattern probably related to preserved lithological structures in the lateritic cover. On plateaus, a significant correlation is observed between kaolinite abundance and vegetation. Recent bush fires are also conspicuous features marked by dark shadings in the three spectral bands.

Reflectance of duricrust plateaus and sandy soils of the valleys are sharply contrasted in the two bands XS1 and XS2. The best discrimination is given by a synthetic index computed as 3*XS1-XS2-100. A halo of higher reflectance surrounds many plateaus like the geochemical halo observed for quartz and zirconium.

Many other objects related to human activities (villages, fields, mining works on gold placers, roads and tracks) are easily identifiable and can be used as landmarks on SPOT images.

The main result of this study is the rather good relationship between spectral reflectance and surface geochemistry in a lateritic environment. Multiple correlation coefficients between reflectance values and major elements, minerals and associated trace elements is generally higher than 0.4. Multispectral SPOT data can be used to modelize geochemical background variation in superficial formations. Many other landscape features identified on these images provide complementary information, which can be helpful at various stages of geological and mineral exploration.

Geochemistry and V.L.F.-EM in sphalerite find near St-Jovite, Canada.

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The Ski Property bordering Lac Labelle, near St. Jovite, Quebec, is in the Grenville lowlands, and is on a north-northeast trend from the Balmat-Edwards zinc mineralization in northwest New York State. Stream-sediment geochemistry on the property and in an area adjacent to it (near Lac Simon) gave multi-element anomalies for Zn and Pb and associated Ba, Hg, Cu, Co and Ni, and a find of sphalerite and pyrite in gravel. The gravel contained 8.85 % Zn, 26.75 % Fe, 9.500 ppb Hg, and gave high values for Cd (130 ppm), Co (104 ppm), Mo (47 ppm) and W (420 ppm). The stream sediment anomalies for Zn and Pb plus Ba, Hg, Cu, Co and Ni, are consistent with mineralization derivation from ore fluids similar to those responsible for Mississippi-Valley type deposits and suggest the existence of an exploration target similar to the Balmat deposit or to the Pierrepont deposit, located about 50 kilometers northeast of Balmat, along the strike of the Balmat fault. Geological mapping of the study area showed the existence of calcitic marble, calc-silicates (15% silicates) paragneisses (some with > 1 % pyrite-pyrrhotite), quartzo-feldspathic rocks, diabase, and associated shear zones.

Follow-up geochemistry on samples from existing outcrops, plus soil geochemistry (for Zn, Pb and Cu) and VLF-EM measurements at 660 sample sites on 25 meter spacing along northwest-southeast trending lines 50 to 100 meters apart gave clusters of strong and moderate anomalies. Seven holes were drilled to test coincident soil geochemistry/VLF-EM anomalies as well as surface showings of up to 1% Zn in bedrock. The most significant mineralization was intersected in two of the holes, one with up to 2 % sphalerite and with 2.2 % zinc in a 2 meter section at a depth of about 133 meters. Associated ore minerals included pyrite, lesser amounts of pyrrhotite, and insignificant amounts of galena and chalcopyrite. The mineralization appears to be related to brecciated marbles within minor fault structures, features common in the Precambrian Grenville series. Additional exploration is planned for the Ski Property and adjacent claims.

A comparison of geochemical exploration techniques and sample media within accretionary continental margins.

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R.M. O'Leary
R.J. Goldfarb

The Pacific Border Ranges of the southern Alaskan Cordillera are composed of a number of allochthonous tectonostratigraphic terranes. These terranes contain mineral deposits characteristic of accretionary continental margins worldwide and include : (1) epigenetic, gold-bearing quartz veins hosted by metamorphosed turbidite sequences ; (2) bands and disseminations of chromite in accreted island-arc ultramafic rocks ; and (3) polymetallic volcanogenic massive sulfide deposits hosted by oceanic volcanic rocks and their adjacent sedimentary units. A geochemical pilot study was undertaken, as part of the U.S. Geological Survey's Alaskan Mineral Resource Assessment Program (AMRAP), to determine the most efficient exploration strategy for locating these types of mineral deposits within the Pacific Border Ranges.

High-density sediment sampling was carried out in first- and second-order stream channels surrounding typical gold, chromite, and massive sulfide occurrences. At each site, a stream-sediment sample and a bulk-sediment sample were collected. In the laboratory, each stream-sediment sample was dry sieved into coarse-sand, fine- to medium-sand, and silt- to clay-size fractions. The bulk-sediment samples were panned to remove lighter minerals and then were split into two parts. One split, termed panned concentrate, was pulverized and analyzed without further processing. The second split, termed heavy-mineral concentrate, was prepared by first allowing the panned sample to settle through bromoform (s.g. 2.85) to remove any remaining light minerals. The resulting concentrate was then divided into magnetic, semimagnetic, and nonmagnetic fractions.

Three methods of analysis were used : atomic absorption spectrometry (AA), inductively coupled plasma spectrometry (ICP), and semiquantitative emission spectrography (SQS). For the AA method, a partial dissolution technique was used employing $HCl-H_2O_2$ digestion followed by 10 % Aliquot-336-in-MIBK solvent extraction in the presence of KI and ascorbic acid. For the ICP method, total digestion was used employing HF, $HClO_4$, and HNO_3. All sample types were analyzed by the SQS method. Additionally, all sediment fractions and panned concentrates were analyzed by AA and ICP. Relatively small sample volumes restricted heavy-mineral-concentrate analyses to SQS.

At the Shell mine within the Kenai Mountains, quartz veins containing gold, pyrite, arsenopyrite, galena, and sphalerite cut turbidite beds of the Late Cretaceous Valdez Group and Tertiary felsic dikes. Gold and silver are the only suitable pathfinder elements for this deposit type because the sulfide minerals associated with the gold veins are also found in many areas that do not contain precious metals. Stream-sediment samples proved useless in detecting the upstream presence of the gold-bearing veins. In contrast, AA analysis of panned-concentrate samples identified moderately strong Au and Ag anomalies as far as 4 km below the deposit and a weak Au anomaly as far as 6 km downstream. Of all the sample types, the strongest geochemical anomalies for both As and Au were found in the nonmagnetic concentrate fractions, but these two elements could not be detected by SQS methods in samples collected farther than 3.5 km from the known gold system.

Chromite occurs within serpentinized dunite and peridotite at Bernard Mountain in the Wrangellia terrane on the north side of the Chugach Mountains. The most extensive anomalies, which occur as far as 10 km below Bernard Mountain, were for Cr in the fine- to medium-sand-size sediment fraction, the panned-concentrate samples, and the magnetic concentrate fraction. SQS analyses delineated the occurrence as well as, or in some cases better than, did the ICP method. High Cr concentrations in the silt- to clay-size and coarse-sand-size sediment fractions were also present but never extended more than 3 km below known Cr-rich deposits. Strong, but much less extensive, anomalies were found for Co and Ni in the magnetic concentrate fraction, for Mg and Ni in the semimagnetic and nonmagnetic concentrate fractions, and for Co, Mg, and Ni in the panned-concentrate samples.

A number of small lenses of massive pyrite, pyrrhotite, chalcopyrite, and sphalerite are hosted by metamorphosed tholeiitic basalt of the Tertiary Orca Group in Vesuvius Valley, along the south side of the Chugach Mountains. These lenses are believed to be small, Cyprus-type massive sulfide deposits formed near an oceanic spreading center. Enrichments of Cu and Zn within the silt- .to clay-size sediment fractions provided the strongest anomalies, with elevated metal values detected as much as 3 to 5 km below the deposits. AA and SQS analyses both identified the Cu-Zn anomalies ; ICP analysis detected only the Zn enrichments at these same distances. The fact that the silt- to clay-size sediment fraction was the only sample medium to yield anomalous metal values downstream from a small glacial lake within the drainage net, approximately 5 km from the deposit, suggests the possible importance of hydromorphic dispersion and subsequent colloidal adsorption during erosion of the sulfide-rich lenses. The panned-concentrate and nonmagnetic concentrate samples show anomalous Co, Cu, and Zn concentrations that extend as far as 2 km below the massive sulfide occurrences. However, no anomalous values for these samples were noted downstream from the lake.

Comparison of the various types of geochemical exploration techniques and sample media shows that an exploration strategy in a typical accretionary continental environment is most efficient when the samples include a fine- to medium-sand-size sediment fraction and some type of heavy-mineral concentrate. Even with the relatively low detection limits of AA analysis, anomalous signatures associated with the gold veins could not be identified in any of the sediment size fractions. If panned-concentrate samples are used, instead of heavy-liquid and magnetic separations, all concentrates should be analyzed by AA for Ag and Au. If magnetic and nonmagnetic concentrate fractions are used in a reconnaissance survey, only the SQS method can be applied.

Comparison between analytical and mineralometric methods on regional exploration of scheelite mineralization in western Zamora (Spain).

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J. Saavedra
M. Viladevall

The aim of the present work was to compare the analytical results of wolfram with the scheelite contents of 300 panning concentrates taken from a drainage network of 150 km^2 in the western part of the province of Zamora (western Spain) in order to develop a valid method for the exploration of scheelite mineralization in similar areas.

The panning concentrates are separated into two fractions : one of them was pulverized for later analysis of W, Sn, Pb, Zn, Cu, Ba and As. The other was employed for the corresponding mineralogical determination and scheelite grain count in the >2 mm grain size fraction, and in the 2-1, 1-0.5, 0.5-0.3, 0.3-0.2, 0.2-0.1 mm range and <0.1 mm fraction.

The results of this research pointed out the presence of disseminated scheelite associated with volcano-sedimentary formations of pre-Ordovician age.

Geochemical signatures of possible deap-seeted ore deposits in Tertiary volcanic centers, Arizona and New Mexico.

C. Watts
J.R. Hassemer

We have identified in the geochemical reconnaissance of an 8 000 sq mi region of the southwestern United States geochemically anomalous zones in Tertiary volcanic centers that appear to reflect subjacent, potentially mineralized plutons and fracture systems. Several deep, large and hitherto unknown targets for base-, precious-, and rare-metal deposits in the subvolcanic environment have been defined by using the ratio :

$$\frac{Ag + Mn + Pb + Zn + Ba}{Au + Mo + Cu + Bi + W}$$

of threshold-normalized elements determined by spectrographic analyses of nonmagnetic fractions of bromoformed and magnetically separated heavy-mineral concentrates derived from stream-sediment samples.

Observations of individual element distributions in both the nonmagnetic and paramagnetic fractions of heavy-mineral concentrates collected in the vicinity of exposed deposits and on the peripheries of mining districts in the region led us to an empirical metal zonation sequence for the region wherein the lateral and vertical periphery of ore deposits is relatively more enriched in the numerator elements, whilst the area proximate to the deposits is more enriched in denominator elements.

Within the study area, geochemically anomalous zones outlined by contour maps of the ratioed data coincide with portions of the peripheries of several, only recently mapped, volcanic centers. These anomalous patterns are interpreted as indicating those ring-fracture segments and ring-fracture intersections most likely to be mineralized. Other maxima cluster within the volcanic centers suggesting subsurface mineralized cupolas or centers of metal-rich hydrothermal systems.

The use of the ratio in a regional setting has allowed us to separate potentially ore-bearing volcanic centers and portions of those centers from probable non-productive centers.

Thème 2 : PROSPECTION OR
Topic 2 : EXPLORATION FOR GOLD

Lithogeochemical and mineralogical indicators of Andean precious metal and polymetallic vein mineralization .

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Regional and mine-scale exploration for epithermal and mesothermal precious and polymetallic vein mineralisation in the Andean Cordillera of Bolivia and Peru has largely depended on the direct investigation of visible expressions of mineralisation such as veins and alteration zones. The utilization of stream sediments and soil geochemistry has been hampered by the effects of contamination related to old mine workings. Lithogeochemical and mineralogical orientation studies of epithermal and mesothermal ore deposits have been carried out in order to (a) verify that lithogeochemistry can be used for the exploration for Andean vein deposits, especially in contaminated areas and (b) investigate the relationship between mineralogical and lithogeochemical alteration haloes in order to see which is the most useful and cost-effective exploration guide.

Lithogeochemical and mineralogical alteration haloes associated with epithermal Ag veins in andesitic volcanics at Millotingo and Caylloma, Peru. and in dacitic volcanics at San Antonio de Lipez, southwest Bolivia, are compared with haloes associated with the higher temperature polymetallic Pb-Zn-Ag-Cu+/-Sn veins (1) in dacitic volcanics at the Gran Chocaya-Animas mine, Bolivia, (2) in metasedimentary rocks at the Colquiri and San Francisco mines, Bolivia, and (3) in shales and sandstones at the Casapalca mine, central Peru.

In all 750 rock samples were collected from surface exposures and in mines by sampling cross-cuts and borehole cores. Si, Al, Ti, Fe, Mg, Ca, Na, K, Mn, Ag, As, Ba, Cu, Pb, Rb, S, Sb, Sr and Zn were determined by XRF analysis using pressed powder pellets. Aqua regia soluble Ag, Cu, Pb, Zn, Mn and Fe were determined by flame AAS while Hg was determined in some samples by flameless AAS. Data interpretation was based on single element, ratio, factor score, principal component score, and normalised data additive plots.

In the dacitic volcanic rocks of the San Antonio de Lipez and Animas-Gran Chocaya areas, constantly or erratically very high levels of Ag, As, Hg, Pb, S, Sb, Zn +/- Sn, Cu accompanied by high K/Na and Rb/K ratios indicate that there is a high possibility of intersecting major vein mineralisation. However, with the type of sampling used there appears to be no consistent gradual increase of these geochemical parameters towards a major vein. Asymmetric hanging wall-footwall haloes caracterise a major Ag-Pb-Zn vein at San Antonio de Lipez. Moderately elevated K/Na, Rb/Sr, Rb/K and Mg/Ca ratios together with the ore elements Ag, As, Pb, Sb and Zn extend at least 300 m from the zone of erratically very high values, thus providing a wide rock geochemical exploration target. K-feldspathisation is closely associated with the vein mineralisation at San Antonio and sericitisation with the higher temperature Pb-Zn-Sn mineralisation at Gran Chocaya-Animas. This mineralogical alteration can be determined chemically using the K/Na ratio and by XRD using the I K-feldspar/I plagioclase feldspar ratio.

Similar, but often less extensive, Ag, As, S, Sb and K/Na haloes in andesitic volcanic rocks are associated with the Ag-Au epithermal veins at Millotingo, Peru. In some cases, R-mode factor score and normalised data additive plots produce smooth lithogeochemical haloes that permit the detection of a vein from 50-60 m when the visible alteration extends for less than 10 m. Such smooth profiles are not always seen, neither is the dispersion always so extensive. In some cases the lithogeochemical halo extends for only 10-15 m from a major vein.

Hydrothermal alteration associated with these vein deposits in volcanic rocks is reflected by regional propylitisation with K-feldspathisation, silicification, argillic, sericitic and silica-alunite alteration more directly associated with the mineral veins. Mineralogical indicators such as calcite and the XRD determined K-feldspar/plagioclase feldspar (Ik/Ip) ratio can be used as guides for distinguishing between apparently similar levels of visible alteration on a regional basis and also in borehole cores. Vein-related mineralogical alteration can also be detected by major element ratios with the advantage that multi-element rock geochemical data is more economically obtained and allows the detection of ore-element dispersion in addition to ore-related hydrothermal alteration thereby making it a more reliable and cost-effective exploration method.

Polymetallic veins in sedimentary and metasedimentary rocks appear to produce less extensive K/Na haloes related to mineralogical alteration, primarily due to the lower susceptibility of these rocks to extensive hydrothermal alteration. However, low amplitude, asymmetric footwall-hanging wall K/Na, Ag, As, Sb, and Zn haloes were detected in hematitic calcareous siltstones and shales at the Casapalca Ag-Cu-Pb-Zn mine in Peru, indicating that K-metasomatism can be detected in some less reactive rock types. The Zn-Pb-Sn vein mineralisation in metasedimentary rocks at the San Francisco mine in Bolivia has no major element haloes, but a supra-ore (hanging wall) arsenic halo extends some 90 metres above a major polymetallic vein.

A combination of single element, ratio and additive plots of normalised data appears to be the most useful methods of data interpretation, although factor and principal component score plots can be used to some advantage when dealing with a wide range of elements.

Lithogeochemistry, especially when used in conjunction with detailed geological mapping, can be a useful aid to the exploration for Andean precious metal and polymetallic vein deposits. It has the capability of indicating the potential of areas of visibly hydrothermally altered rocks. The recommended approach is to use multielement lithogeochemistry as a guide to both the mineralogical alteration aloes and dispersion of the ore elements accompanied by limited mineralogical investigations to identify hydrothermal alteration parageneses.

Signatures géochimiques des shear-zones aurifères.

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La signature géochimique d'une minéralisation découle des paragenèses sulfurées qui les caractérisent, ainsi que des modifications subies par les roches encaissantes sous l'action des phénomènes hydrothermaux associés à sa mise en place. Elle peut être utilisée pour établir une classification des structures minéralisées en fonction des anomalies (en roche, ou lorsque les conditons le permettent, en sol) qu'elles provoquent dans un environnement lithologique donnée.

Ainsi, on distinguera trois types d'éléments chimiques dans cette signature :

- les éléments majeurs déjà présents dans les roches encaissantes, et dont les proportions ont été modifiées par l'introduction de la minéralisation ; ceux-ci seront écrits en tête de la signature entre des [ ], précédés ou non d'un signe + lorsqu'ils traduisent un enrichissement, et précédés d'un signe - lorsqu'ils traduisent un lessivage ;

- les éléments absents des roches encaissantes et introduits par les phénomènes minéralisateurs qui caractérisent la minéralisation à l'échelle de la structure (échelle semi-stratégique) et donc présents en tout point de celle-ci. Ils seront écrits à la suite des précédents ;

- les éléments spécifiques des zones riches qui sont associées à un phénomène de remobilisation et de concentration. Ces derniers, qui constituent des traceurs tactiques de la minéralisations seront écrits entre ( ) à la suite des précédents.

En France, la majorité des structures en cours d'étude présenterait la signature suivante :

$$\left[+SiO_2, +Fe_2O_3, -TiO_2\right] As, Sb (Pb)$$

Les traceurs semi-stratégiques semblent refléter des caractéristiques géologiques régionales qui pourraient être mises en relation avec des contextes géodynamiques spécifiques, mais ceci reste pour l'instant du domaine des hypothèses. Quoiqu'il en soit, des constantes apparaissent nettement dans un certain nombre d'exemplesrégionaux :

L'arsenic est toujours présent dans les shear zones aurifères du socle varisque français. Il s'observe également dans ces mêmes structures affectant les formations volcano-sédimentaires du bassin de Cadillac (Québec, Canada). Par contre, cet élément est généralement peu présent dans les shear zones de la greenstone belt d'Abitibi où il pourrait être remplacé par le cuivre : dans un contexte analogue, certaines shear zones ne renfermeraient pas de traceurs semi-stratégique (Repentir, Guyane).

L'antimoine, traceur semi-stratégique, semble caractéristique des structures du Massif Central.

Par contre, le plomb, traceur tactique, semble indépendant de l'environnement lithologique de la shear zone. Plus étroitement liés à l'or que les traceurs semi-stratégiques, il signe les zones riches de la majorité des structures étudiées. Son utilisation en tant que guide de prospection est toutefois liée à son niveau de teneur dans le minerai.

Soil geochemistry of Mother lode-type gold deposits in the Hodson mining district, central California, USA.

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R.H. Hill

The Hodson mining district is in the westernmost foothills of the Sierra Nevada in California, about 17 km west of the town of Angels Camp. This district is part of the West Gold Belt, which lies about 12 to 16 km west of, and generally parallel to, the better known Mother Lode Gold Belt in central California. The district produced several million dollars worth of gold between about 1890 and 1940.

The geologic setting and mineral deposits in the West Gold Belt are generally similar to those in the Mother Lode Gold Belt. Rocks in the area investigated are all of Jurassic age and consist of a mixture of (1) fine-grained, generally thin-bedded, clastic sedimentary rocks that have been metamorphosed to slates, schists, and phyllites, and (2) massive volcanic flows and welded tuffs that have been metamorphosed to greenstones. All these rocks were intensely faulted and folded during the Late Cretaceous Nevadan orogeny ; northwest-bearing faults seem to be the most dominant. Mining in the area was of low-grade gold-pyrite ores that occurred principally in the wall rocks adjacent to the major Hodson fault and its splays. Minor amounts of other sulfide minerals are locally associated with the gold deposits.

The study area is one of moderate relief, with elevations ranging from about 300 to 420 m. The area receives about 500 to 700 mm of rain each year, and almost all precipitation falls between November and April. Temperatures range from about 0 to 33°C. This climate has produced a well-developed soil profile that is as much as 1 m thick. Soils cover most of the area ; outcrops are generally restricted to isolated areas of silicified greenstones.

Samples were collected from the top of the B soil horizon, which most commonly occurs at depths of 10 to 30 cm. Most sampling was done at 10-m intervals along traverses crossing faults known to be associated with Au-mineralization. This detailed sampling extended to distances as much as 100 to 200 m from the centers of these faults ; additional samples were collected at more irregular intervals and at greater distances from these faults. Soil pH was determined for each sample. All samples were then wet-sieved to remove clay minerals and organic materials, and the 0.50- to 2.00 mm fraction was retained for analysis. The samples were pulverized and analyzed for thirty-on elements (Ag, As, Au, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, La, Mg, Mn, Mo, Nb, Ni, Pb, Sb, Sc, Sn, Sr, Th, Ti, V, W, Y, Zn, and Zr) by semi-quantitative emission spectroscopy and for eleven elements (As, Au, Bi, Cd, Hg, Mo, Sb, Te, Tl, W and Zn) by wet chemical methods. Of these elements, twelve Ag, As, Au, B, Cu, Hg, Mn, Pb, Sb, Te, W and Zn, all seem to show anomalous distributions that are spatially related to the Au mineralization.

Gold anomalies are closely associated with many of the known faults ; in some cases Au (and other element) anomalies are present where no such structures have as yet been identified during mapping. Mercury anomalies are weak and are generally restricted to an area within 10 to 20 m of known mineralized faults. Zinc and Mn most commonly form negative anomalies in the vicinity of the mineralized structures, apparently as a result of chemical leaching of these elements in the low pH (about 4.0 to 6.2) soil environment that is created by oxidizing pyrite. Anomalies for Cu and Pb are erratically distributed ; in some cases they are associated with Au mineralization, but not in other cases. Anomalies for these two elements are rarely present more than 50 m from the mineralized structures.

In addition to Au, anomalies for six elements (Ag, As, B, Sb, Te and W) generally form the broadest haloes around the mineralized faults. These haloes may extend for more than several hundred meters beyond the faults. Our observations thus indicate that these six pathfinder elements, as well as Au, should be particularly valuable in geochemical exploration surveys conducted in the Mother Lode Gold Belt and its smaller adjacent belts. Of this group of six pathfinder elements, Te shows the highest anomaly contrast and is known to be relatively immobile in the weathering environment. These observations suggest that Te may be a better pathfinder than As (an element that has been commonly used in geochemical exploration for many types of Au deposits) for use in reconnaissance surveys to identify new areas of Mother Lode-type Au mineralization.

Gold and associated elements in lake sediments : their application to gold exploration.

J.W. Mc Connell
P.H. Davenport

This paper describes the results of an investigation of the application of lake sediment geochemistry to exploration for gold mineralization. In Canada, the effectiveness of lake sediment geochemistry in delineating areas mineralized with base metals, uranium, tungsten, and rare earth elements has been well documented, but its effectiveness in reflecting gold occurrences is less clearly demonstrated. Specifically documented examples of the response of gold in lake sediment to gold mineralization, the identification of distinctive trace element associations, the determination of adequate sample size and the analytical reproducibility of both site and laboratory duplicates are lacking.

In this study, Newfoundland lakes were sampled, many in duplicate, in areas with various types of gold mineralization and in areas regarded as background. In addition to gold, sediment was analysed for Ag, As, Br, Cd, Ce, Co, Cr, Cu, F, Fe, Mn, Mo, Nb, Ni, Pb, Se, Sb, Th, W, Y, Zn and Zr and loss-on-ignition as an estimate of organic carbon.

Results to date indicate that anomalously high gold values in sediment are present in many lakes in proximity to mineralization. Examples include the Hope Brook and Cape Ray deposits. The reproducibility of gold analyses from duplicated lake sites is fair, particularly in the higher range. Nonetheless, gold data are "noisier" than base metal data from the same samples.

Dispersal patterns of "pathfinder" elements are present at some deposits and may be larger and more uniform than that of gold. However, their character is dependent upon the element association in the particular deposit hence it varies widely among deposits or may be lacking entirely. Promising pathfinders include Ag, As, Cd, Cu, F, Pb, Se, Sb and W.

The choice of analytical method for gold is significant if lower range values are required. One set of samples was analysed by two methods. Of samples analysed by graphite furnace atomic absorption method 11 % were below the detection limit of 0.5 ppb. Of samples analysed by delayed counting neutron activation 23 % were below the detection limit of 2 ppb. In fifty percent of samples from predominantly background areas which were analysed solely by neutron activation gold was below the detection limit.

Preliminary conclusions are that gold in lake sediment delineates mineralized areas. Gold data are noisier than comparable base metal data. High values should be confirmed by reanalysis. The fact that most repeat analyses of samples with high initial gold values reproduce well while some differ radically suggests that gold is usually quite homogeneously distributed (precipitated ?) but that sometimes it occurs as discrete concentrations (particles ?). A relatively small sample size should be adequate to obtain meaningful gold analyses if gold is uniformly distributed within the sample material but adequate sample size where gold occurs concentrated in a minor phase is problematical. The presence or absence of pathfinder elements is dependent upon the nature of the target mineralization.

Effects of valley and local channel morphology on the distribution of gold in stream-sediments.

S.I. Day
W.K. Fletcher

Prospectors and exploration geochemists are well aware of the erratic nature of the distribution of gold in sediments from a single drainage basin. However, quantitative data on the effects of fluvial geomorphology are lacking because most exploration surveys do not take into account the extreme rarity of gold particles in sediments. Here, we present data from detailed bulk sampling of sediments from a short reach of a mature stream in British Columbia, Canada.

Ten sites on a study reach 5 km long were sampled in June 1986, immediately after the peak of the spring meltwater flood. At each site, typically a point or channel bar, two samples were taken from erosional (winnowing) and depositional environments to provide a comparison of contrasting local hydraulic conditions. At each sampling location, sufficient sediment was processed to yield 60 kg of minus 2 mm sediment. The plus 2 mm fraction was retained and field sieved to provide a complete textural analysis.

In the laboratory, each sample was wet and dry sieved to yield eight fractions between 2000 μ and 53 μ. Magnetic minerals were separated from five dry fractions in the range 420 μ to 53 μ and from a slurry of minus 53 μ sediment. Neutron activation analysis was used to determine gold in two non-magnetic heavy (S.G. ≧ 3.3) mineral concentrates (- 105 + 74 μ and - 74 + 53 μ) and non-magnetic minus 53 μ sediment. The expected number of gold particles in each fraction was estimated and confidence limits for the analyses were determined assuming a Poisson distribution (standard error = 200/ n, were n is the number of gold particles). Sufficient numbers of particles are present in most samples to allow erosional and depositional samples to be statistically distinguished.

Although the reach is short and relatively distant from the watershed several changes of channel morphology are seen which influence the relative concentrations of heavy minerals in the sediments. Two kilometres downstream of the uppermost sampling site a steep, ephemeral tributary adds relatively coarse sediment to the main channel causing it to steepen locally (slope = 0.04), producing a braided channel pattern. Within 1 km, the effect of the tributary is overcome : the channel slope decreases to 0.03 and meanders with gravel point bars become dominant. Coarse (- 420 + 210μ) magnetic mineral and finer (- 105 + 74μ) gold fractions reflect these changes in slope. In steep braided sections, the average relative difference between erosional and depositional samples is small (typically gold content of erosional samples is an order of magnitude higher than that of depositional samples), however, as the slope decreases downstream the average concentration of heavy minerals in erosional sites increases. Conversely, average gold content of depositional sites decreases downstream to yield a much greater difference between erosional and depositional samples (two to three orders of magnitude). It appears that in steeper sections, erosion of dense sediment occurs allowing concentrations of heavy minerals in depositional environments to approach those of erosional environments. As the slope decreases dense minerals are not eroded and depositional sites have low heavy mineral concentrations.

Changes of heavy mineral concentrations is erosional and depositional samples as grain size decreases reflect local (within site) hydraulic effects. In the coarser fractions, erosional sample heavy mineral concentrations are consistently greater than those for depositional samples. However, at four sites, as grain size decreases heavy mineral concentrations in depositional samples approach and surpass the corresponding erosional sample concentrations. This trend cannot be explained by depositional processes alone. As the water level in depositional pools drops, the stream bed is scoured producing observable black sand accumulations and extremely anomalous gold concentrations.

The minus 53 μ fraction is atypical in that erosional and depositional samples show very similar gold and magnetic mineral concentration trends. As has been observed elsewhere it appears that at small grain diameters density becomes unimportant in determining sediment transport rates.

Results show that conventional exploration samples of sand-size sediment (minus 105 μ) must be obtained by processing at least 350 kg of sediment from erosional (winnowing) environments. Although smaller volumes of sediment must be processed at sites of deposition, the results are likely to be very erratic. Between site variability may be reduced by avoiding sample sites downstream of tributaries where the main channel pattern has changed significantly. The minus 53 μ fraction provides an unconventional alternative sample provided that there is significant silt- and clay-sized gold in the sediments. Sufficient minus 53 μ sediment for neutron activation analysis can be obtained from a small field sample (less than 5 kg of minus 2 mm sediment) and a heavy mineral concentrate does not need to be prepared.

Geochemistry of fluid inclusions in gold-bearing shear-zones : the Cros-Gallet deposit (France) and the Sanoukou prospect (Mali).

P. Hubert
C. Beny
J.Cl. Touray

A fluid inclusion study was carried out on two deposits both located in large shear zones of several kilometer extent. These deposits have a comparable paragenetic sequence : an early mineralization with arsenopyrite, pyrite, native gold and a later one with Pb-Ag-Cu sulfosalts, electrum and galena.

This study showed that the thermobarometric evolution of fluids was similar in both deposits and occurred in two stages :

. The first one (fluid inclusions from the H_2O-CO_2-NaCl(CH_4N_2) system) corresponds to a drop of pressure in a lithostatic regime. It is in relation with the early Au, As ore deposition.

. The second stage which is characterized by a drop of temperature (fluid inclusions from the H_2O-NaCl system) corresponds to an opening in a hydrostatic regime. It is associated with Au, Pb, Sb ore deposition.

An application of this model to estimate the gold potential of the quartz samples was carried out at Sanoukou using a global destructive analysis of the fluid inclusions. This method allowed to assess, in a given sample, the relative importance of the two established stages and demonstrated that the gold rich quartz (Au content $>$ 1 ppm) was consistently affected by the late aqueous stage. Utilization of this result could be considered in prospecting.

Mineral exploration for gold bearing horizons in the central-western zone of Asturias (Spain).

J. Iglesias
J. Loredo
F. Ruiz

In the Midwestern Cantabrian mountain range of Asturias, Spain, gold mineralization is common and, locally, was worked at the surface by the Romans. Most of this mineralization is connected to predominantly dolomitic limestone horizons corresponding to Lower-Middle Cambrian, although sometimes within detrital layers (quartzites) as well. Locally igneous outcrops, such as granodiorite and gabbro, are observed near mineralized occurrences.

Mineral exploration combining geochemistry and other exploration techniques were applied in the area where several types of mineralization are related both to calcareous formations (Navelgas, Abaniella, Begega) and to quartzitic or sandstone-like horizons (Antonana, Castro de la Grueba). In the mineralized areas the rocks show different epigenetic alterations : dolomitization, chloritization and, mainly, silicification which is more important near fractured zones where millimetre thick quartz veinlets are common.

On a regional scale the structural analysis of the fracture network confirms the presence of two N 40° and N 110°E trending fracture systems. The mineralization is linked to these fracture systems, at least on the deposit scale, as gold is commonly associated with quartz-filled veins following this orientation. Some of the igneous outcrops are connected with these fracture systems as well.

Gold particles alove 2 µm are in limited number in the studied samples but very small particles $\leqslant 1$ µm, sometimes difficult to characterize by reflected light microscopy, are abundant. Gold particles are usually associated with quartz or secondary iron oxides but are always related to fracture zones. The intense supergene alteration impedes identification of the primary sulphide minerals related with gold but pyrite is probably one of them.

Alluvial prospecting is particularly useful when the watercourses cut across the structural lineaments associated with gold bearing horizons. The situation of the mineralization is indicated by the presence of gold particles in the panning concentrates downstream from an horizon whereas the panning concentrates upstream of this horizon do not contain gold. Besides the gold particles, measuring from 10 to 20 µm and exceptionally 50 µm, decrease in number downstream of a mineralized horizon.

From the study of 84 samples the multi-element (Au, Cu, Pb, Zn, Mn, Ag, As, Ba, Bi, Sb, Hg, Mo, Te) rock geochemistry and corresponding principal component analysis show that Au, Ag and Hg are well correlated. The study indicates also that the highest gold contents are connected with high density of quartz veins in the rock.

The multi-element (Au, Cu, Pb, Zn, Mn, Ag, As, Ba, Bi, Sb, Hg, Mo, Te) soil geochemistry carried out on 136 samples from a traverse in topographic high in order to avoid contamination from ancient open-pits and application of principal component analysis to the data, show a poor correlation between gold and the remainder elements ; and the association Au-Ag-Hg present in rock geochemistry disappears.

Geophysical prospecting including induced polarisation and magnetometry did not reveal significant anomalies in the mineralized areas except Carles and Boinas which are connected with Devonian igneous rocks and not with Cambrian limestones. In Carles, where a magnetite-bearing skarn exists, the response to magnetometry is positive.

The mineralization is related to fracturing and alteration process in favourable horizons ; lithology, stratigraphy and tectonics may be considered as the first exploration criteria. The only common processes in the different types of mineralization are generally fracturing/brecciation and silicifiation.

The determination of possible igneous intrusions -some of which crop out at the surface- which seem to be related to gold-bearing horizons and the determination of alterations, probably more intense near the mineralization, will permit to define the most favourable zones and to use alterations as successful prospecting guide.

The use of Tl/Eu ratios in precious metal exploration.

M. Ikramuddin

Element ratios based on Tl, Rb, K, Ba, and Sr have been found in the past to be useful guides in mineral exploration. Hydrothermally altered and mineralized rocks generally contain low Ba/Tl, K/Tl, K/Rb, and Ba/Rb ratios and high Tl/Sr and Rb/Sr ratios. Recent studies by our research group on a large number of precious metal deposits indicate that K/Tl and Ba/Tl ratios are better indicators of mineralization than several other element ratios mentioned above.

In order to expand our studies further on the use of element ratios in mineral exploration, we have obtained data on Tl/Eu ratios in a variety of precious metal deposits hosted by igneous, sedimentary, and metamorphic rocks. The deposits studied are located in the Republic mining district, Washington ; the Como mining district, Nevada ; the Howard and Cracker Creek mining districts, Oregon ; and the North and South Moccasin mining districts, Montana.

Several recent studies have indicated that Tl^+, which is similar to Rb^+ and K^+, shows a progressive increase during magmatic differentiation and is highly enriched in hydrothermal fluids. In contrast Eu^{+2}, which is similar to Sr^{+2} and Ca^{+2}, shows a progressive decrease during magmatic differentiation and is extremely depleted in hydrothermal fluids. These data suggest that Tl and Eu have a greater sensitivity to hydrothermal processes and hence Tl/Eu ratio may be of significant use as a guide to mineralization.

The data obtained in this study on various types of gold and silver deposits indicate that in all the mineralized areas there is significantly less Eu in hydrothermally altered rocks than in unaltered rocks. The Tl/Eu ratios in mineralized rocks are significantly higher than those in unmineralized rocks and the range of values of this ratio in hydrothermally altered rocks does not overlap with the range in unaltered rocks. The Tl/Eu ratio appears to have a distinct advantage over other ratios in separating the rocks into different populations ; in some cases, it is even possible to separate hydrothermally altered mineralized rocks from hydrothermally altered unmineralized rocks. Since during supergene alteration of rocks Tl and Eu may behave similarly, Tl^+ oxidizing to Tl^{+3} and Eu^{+2} to Eu^{+3}, the Tl/Eu ratio can prove to be more useful than Tl/Sr and Rb/Sr ratios.

Geochemical exploration of the Célina Mokrsko gold district in the Jilove Belt, Bohemian massif, Czechoslovakia.

J. Janatka
P. Moravek

Gold mineralization in the Bohemian Massif was for long years considered to be connected with granitic intrusions. Following a new model of metallogeny of gold, the main attention was given to areas containing volcanosedimentary formations.

The largest structure of this rock type of Proterozoic age, Jilové Belt, shows similarities to Archean greenstone belts.

Therefore, regional geochemical sampling as well as geological mapping was undertaken in the whole area. Soil samples were analyzed for 20 trace elements, including gold. There was found interesting zoning in the belt, with increase of base metals concentrations southwards and of gold northwards. Base metals haloes (Cu, Zn, partially Ni) indicate presence of stratiform sulphide mineralization recently under research. Gold haloes with concentrations over 1g/t and with pathfinders typical of the variscan mineralization (As, Bi) were found in old mining districts and in new untouched areas as well. In the most promising area -the Psi hory district- detailed soil sampling was realized. Results of this exploration proved presence of new zones of gold mineralization, which were drilled. Besides other indications, two new dominant structures - Celina and Mokrsko - were located. Stockwork-type gold-bearing quartz mineralization was found with accessory sulphides Bi and Te minerals and scheelite. Thickness of veins reaches tenth up to hundreds of meters with an average gold grade of 2 g/t.

In the present study, nearly 6500 analyses of samples from the Celina deposit were processed using standard statistical and multivariate methods. Based upon this, three main groups of elements different in their geochemical behaviour were distinguished. The first group, represented by Co, Cu, Ni, Zn and partially W is connected with lithology. Nevertheless, these elements (except W) form narrow negative primary haloes contouring quartz stock works. The second group of elements included the gold mineralization elements and pathfinders (Au, Bi, Mo, W) whose distribution is spatially limited to the quartz mineralization. The third group of elements is represented by As, B, Sb, and is characterized as group of halo-forming elements prevailing either in upper parts of mineralization of being in relation with tectonics. Ambivalent behaviour of tungsten probably reflects connection of the stratiform scheelite and the gold mineralization in one mineralization period, although being developed in different structural position. Based upon the primary haloes research, new criteria for the search of blind orebodies were defined.

Geochemical signature of gold-bearing silica-barite formations in the Ariab district. Red Sea Hills, Sudan.

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F. Cottard
Y. Deschamps
Y. El Samani
L. Viallefond

The Ariab district is located within an extensive volcanosedimentary belt in northeast Sudan. Seven recently discovered polymetallic massive sulphide deposits (F. Cottard et al., 1986) contain economically interesting gold concentrations.

The gold mineralization occurs in the hydrothermalized and brecciated portions of acidic volcanics intercalated in the massive sulphide bodies and deriving gossans.

A geochemical study based on multi-elements analyses (1) was performed on Hassai and Southwest Hadal Awatib, two of the main deposits of the District : systematic rock sampling was carried out on 50 m spaced surface profiles ; core and percussion drilling samples wera also analysed.

The results obtained from the surface samples revealed two clearly different polymetallic signatures associated either with the various gossans and/or sulphides oxidized to varying degrees, or with commonly baritic, siliceous acidic volcanics hosting the gold mineralization.

Besides Ba, the characteristic elements of the silica-barite formation are Sb, Sn, Ag and Pb. The gossans themselves display highly anomalous As and/or Cu, Zn, Mo and Bi values.

The presence of these two different associations in the drilling samples shows that the silica-barite formation does not derive from a supergene phenomenon but from a primary process associating intense hydrothermal leaching, silicification, barite impregnation and gold mineralization also signed by various characteristic trace elements.

The results of the geochemical study were then applied to further regional exploration, and the various showings discovered during the general survey of the overall volcanic formation were classified, according to their accompagnying trace elements, as targets favourable for gold or for sulphides.

References :

F. Cottard, Ch. Braux, Ph. Cortial, Y. Deschamps, Y. El Samani, A.M. Hottin, M. Omar Younis (1986) - Les amas sulfurés et les minéralisations aurifères du district d'Ariab (Red Sea Hills, Soudan). Historique de la découverte, cadre géologique et principaux caractères des gisements. Chron. rech. min., n° 483, 1986, pp. 19-40, 15 fig., 3 tabl.

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(1) I.C.P. : SiO^2, Al^2O^3, Fe^2O^3, CaO, MgO, K^2O, MnO, TiO^2, P^2O^5, Li, Be, B, V, Cr, Co, Ni, Cu, Zn, As, Sr, Y, Nb, Mo, Ag, Cd, Sn, Sb, Ba, La, Ce, W, Pb, Bi, Zr.
Atomic absorption : Au

Geochemical prospecting for gold in the county of Jamtland, upper central Sweden.

O. Toverud

In 1982 a reconnaissance geochemical till sampling survey was performed by Terra Swede AB in the county of Jämtland in upper central Sweden within an area of 37780 km^2 using a sampling density of 1 sample/39.1 km^2.

Six areas anomalous in gold were thus indicated where further regional surveys of 1 sample/4.4 km^2 and analysis of the fine fraction (-0.5 mm) of till were done in 1983. Two of the areas are located in the eastern part of the county where LKAB Prospektering since 1978 has been prospecting mainly for tin and tungten. In the Räggen area, where the company in 1980 localized a minor tin-mineralization, a follow-up survey was carried out in the fall of 1983 with a sampling density of 1 sample/0.5 km^2 and 1 sample/0.1 km^2 respectively.

During the summer of 1986 bedrock mapping and ore boulder tracing was done along minor bush roads in an area south-west of the village of Bispgården (in eastern Jämtland) where four samples of till anomalous in gold (5-6 ppb Au) were obtained in 1983.

The geochemical and geological work in the area of Räggen has so far not turned up any mineralized bedrock of gold. However, in the area of Bispgården the occurrence of gold is confirmed by analysing pyrite-chalcopyrite bearing boulders and bedrock collected close to the anomalous sample sites of till. In one of the sample sites a 35 kg composite sample was taken of a silicified pyritic bedrock exposed in a road-cut. Analysis of four subsamples of the composite sample gives a mean value of 2.5 g/t Au. The Bispgården target area is presently tested by diamond drilling.

It is shown that a wide sampling grid (1 sample/39/1 km^2) using fine fraction of till samples can successfully be used in indicating gold bearing areas in the gneissic-metasedimentary rocks (in younger plutonites) of eastern Jämtland.

Géochimie de la minéralisation aurifère à la mine Eldrich, région de Rouyn-Noranda, Québec, Canada.

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G. Perrault

La mine Eldrich est un gisement d'or localisé dans une zone de cisaillement et d'altération hydrothermale au sein du batholite de Flavrian. Le batholite, d'une superficie de 75 km^2, de même que les roches volcaniques qui l'encaissent sont d'âge Archéen et font partie de la ceinture volcanique de l'Abitibi, une des sous-provinces du Bouclier canadien. Les études détaillées démontrent que le batholite est composé des unités suivantes, de la plus ancienne à la plus récente : 1) le gabbro quartzifère de Méritens ; 2) la trondhjémite ; 3) la tonalite et 4) la diorite Eldrich. Les roches du batholite et les volcanites-hôtes ont subi un métamorphisme régional dont l'intensité se situe au faciès des schistes verts, zone de la chlorite.

Contrairement à la plupart des mines d'or de la région, le gisement Eldrich n'appartient pas au type filonien. Il consiste plutôt en un amas de roches broyées, altérées et minéralisées en or au sein d'une zone de cisaillement et de direction NNE à faible pendage vers le SE. A l'intérieur de cette zone, la carbonatation, la pyritisation et l'albitisation sont les altérations dominantes. L'or est intimement associé à la pyrite et est généralement présent dans les microfractures à l'intérieur de cette dernière. La déformation, l'altération et la minéralisation affectent également tous les types de roches (trondhjémite, tonalite et diorite), sauf le gabbro quartzifère qui est absent de la zone minéralisée. Les analyses d'éléments majeurs montrent un enrichissement en Na_2O, CO_2 et S et un appauvrissement en SiO_2 et K_2O dans les roches minéralisées. Au point de vue pétrographique, ces variations chimiques se traduisent par une augmentation des quantités d'albite, de carbonate et de pyrite, et par la déstabilisation des amphiboles et de l'épidote à l'intérieur de la zone minéralisée.

La carbonatation se manifeste par une forte augmentation du CO_2 dans toutes les roches minéralisées ; d'autre part, la teneur en CaO demeure stable dans les trondhjémites minéralisées, tandis qu'elle augmente modérément dans les tonalites et les diorites. Ces résultats indiquent que le calcium des carbonates provient principalement des silicates calciques qui sont transformés en calcite, chlorite et quartz lors du processus de carbonatation. La pyritisation se traduit par un enrichissement prononcé en S au niveau de la zone minéralisée, tandis que les teneurs en fer total demeurent relativement stables. Ainsi, le fer nécessaire à la formation de la pyrite proviendrait essentiellement des roches-hôtes. L'albitisation entraîne un enrichissement prononcé en Na_2O et la formation d'une deuxième génération d'albite dans les roches minéralisées. Sous le microscope, cette albite d'origine hydrothermale est parfaitement limpide et se distingue nettement de l'albite métamorphique présente dans les roches non-minéralisées, qui est remplie d'inclusions de clinozoïsite ou de carbonate. Même si les veinules de quartz sont relativement abondantes dans la zone minéralisée, cette dernière montre dans l'ensemble une désilicification, comme en témoigne l'appauvrissement en SiO_2 observé dans les analyses. Ces veinules de quartz proviennent vraisemblablement de la silice libérée lors de la carbonatation des silicates calciques, une certaine quantité de cette silice ayant tout de même été lessivée lors du processus d'altération.

Dans le but de définir les caractéristiques géochimiques du minerai aurifère, trente-trois éléments en traces ont été analysés dans des échantillons provenant de la zone minéralisée, et les résultats ont été comparés avec ceux de roches non-altérées et non-minéralisées du batholite. Les résultats obtenus sont étonnants et démontrent que le gîte Eldrich est nettement distinct des minéralisations d'or filoniennes qui caractérisent la ceinture Abitibi. En effet, dans ces dernières, des éléments comme As, Sb et W sont communément enrichis dans dees proportions variant entre 100 et 10 000 fois le bruit du fond, tandis que dans le minerai de la mine Eldrich, douze éléments montrent un facteur d'enrichissement inférieur à 2,5 (As, Sb, W, Cr, Co, Th, U, Be, Cu, Li, Ni et Pb) tandis que vingt autres ne montrent aucun enrichissement ou des pertes pouvant atteindre 50 % (Sc, Cs, Ba, Hf, Ta, Rb, Sr, V, Zn, Mn et les ETR : La, Ce, Nd, Sm, Eu, Gd, Tb, Tm, Yb et Lu). De tous les éléments en traces analysés, seul l'or montre un fort enrichissement, de l'ordre de 7 000 fois le bruit de fond (moyenne de la zone minéralisée = 5 800 ppb pour un bruit de fond de 0,8 ppb). Ces résultats sont en accord avec l'absence de scheelite et la rareté de sulfures autres que la pyrite (arsénopyrite, chalcopyrite, sphalérite et galène) dans la zone minéralisée. De plus, même si les éléments B et Te n'ont pas été analysés, la tourmaline et les tellurures n'ont pas été observés dans le minerai. La rareté de ces minéraux, qui sont généralement typiques des gisements d'or de l'Abitibi, confirme le caractère particulier du gisement Eldrich. Le titre moyen de l'or, tel que déterminé à la microsonde sur des grains individuels, est de 92,7 % Au et 7,3 % Ag en poids. Même si Ag n'a pas été analysé dans les roches, on peut en conclure que cet éléments doit être enrichi d'un facteur d'environ 10 fois dans la zone minéralisée.

La zone de cisaillement contenant la minéralisation a été reconnue sur une distance d'au moins 3 kilométres. Quant à la zone minéralisée, elle mesure environ 600 mètres le long du cisaillement par 100 mètres de largeur en surface (épaisseur réelle = 10 à 30 mètres). A l'échelle régionale, le meilleur critère de prospection lithogéochimique est l'enrichissement en Na_2O qui est présent sur toute la longueur de la zone cisaillée (3 000 mètres) et sur des largeurs variant entre 200 et 400 mètres. Les anomalies positives en CO_2, S et Au, et négatives en SiO_2 et K_2O sont plus restreintes et dépassent à peine les dimensions de la zone minéralisée.

Un levé pédogéochimique (humus) a également été effectué dans la région de la mine Eldrich. L'humus a été analysé pour Au, Ag, Cu, Ni, Sb et Zn. Les analyses démontrent que la teneur régionale en or de l'humus est de l'ordre de 15 à 20 ppb et qu'elle augmente entre 30 et 70 ppb au-dessus de la zone minéralisée. L'anomalie en or dans l'humus s'étend sur environ 600 mètres au-dessus du gisement par une largeur variant entre 20 et 500 mètres. Cependant, les éléments Ag, As, Cu, Ni, Sb et Zn ne donnent pas d'anomalies significatives, un résultat prévisible si l'on considère qu'ils ne sont pas enrichis de façon importante dans les roches minéralisées sous-jacentes.

La recherche de l'or primaire dans le massif Armoricain (France) : approches géochimiques et minéralogiques combinées.

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De nombreuses concentrations d'or alluvionnaire, d'importants vestiges de travaux miniers datant de l'époque gallo-romaine, des indices aurifères et deux gisements d'or exploités au début du siècle (la Lucette, 8 t et la Bellière, 10 t) sont à l'origine des recherches entreprises par le BRGM depuis 1983 dans le Massif Armoricain dans le cadre de l'Inventaire du territoire national.

La mise en oeuvre simultanée ou en relais des techniques géochimiques et minéralogiques aux différents stades des recherches, a conduit à circonscrire une douzaine de nouveaux districts aurifères, à découvrir des indices d'or totalement inconnus il y a seulement 2 ou 3 ans et à ébaucher la typologie de ces minéralisations.

La démarche suivie s'appuie sur l'étude des minéraux lourds, extraits à la batée ou par liqueur dense, aussi bien d'alluvions et d'éluvions que de roches, "cuttings" ou sédiments de foration préalablement broyés, ainsi que sur des prospections géochimiques plus conventionnelles, mono ou multiélémentaires.

Dans le district de Château Gontier (Mayenne), des minéralisations de type stockwerk quartzo-carbonaté à sulfures (pyrrhotine, mispickel, pyrite, blende, chalcopyrite, etc...) et or contrôlées par des accidents directionnels sur plus de 50 km d'extension et jalonnées par des anciennes aurières, ont été recoupées par tranchées et sondages carottés (traversées métriques à 5 à 28 g/t Au).

Elles sont encaissées dans les formations détritiques du Briovérien (Protérozoïque sup.), dans une région au relief peu accentué et assez bien drainée, mais masquée en partie par des recouvrements de limons.

C'est la prospection alluvionnaire régionale (1 concentré par km^2) qui a individualisé en premier lieu de vastes zones à or libre, en bonne concordance avec des anomalies B-As-Li mise en évidence ultérieurement par prospection géochimique stratégique multiéléments (3 éch./km^2) qui n'incluait cependant pas le dosage de l'or. La superposition des anomalies As-Pb issues de cette même campagne stratégique et des secteurs à or éluvionnaire récupérable par technique gravimétrique, reconnus à maille plus serrée (250 x 250 m), a permis une première sélection régionale des principales zones potentielles d'or primaire. Cette sélection a pu être affinée par une campagne de prélèvements de sols en fonds de vallon à la maille de 10 éch./km^2 analysés pour or et arsenic. Enfin, à l'échelle des prospects, les meilleures réponses pour la recherche de l'enracinement des minéralisations ont été obtenues par des prélèvements à intervalles décamétriques au bed-rock le long de profils espacés de 100 m à 50 m, avec analyse de la fraction granulométrique <125 µ.

Dans le district de Moisdon-Angers (Maine-et-Loire, Loire Atlantique), également caractérisé par un relief peu marqué, des sols résiduels peu évolués et des plaquages de limons pliocènes, des minéralisations aurifères de type "stratabound" ont été mises en évidence. Elles sont localisées dans les formations gréseuses du toit des arkoses de Bains (Cambro-Arenig) affectées par des accidents cisaillants et suivies sur plus de 60 km d'extension : elles sont exprimées sous forme de stockwerk de quartz à sulfures (mispickel et pyrite dominants) et or libre et ont été reconnues par tranchées et sondages carottés (traversées métriques à 4 ou 5 g/t Au).

Prospection alluvionnaire à maille kilométrique et prospection éluvionnaire à la maille de 250 m x 250 m, guidée par la présence d'anciennes exploitations aurifères, sont à l'origine de la découverte des premiers indices et de la localisation d'un niveau de grès porteur de l'or. Une vaste anomalie géochimique As et localement Pb, issue de la prospection régionale multiéléments, trace régionalement ce niveau porteur.

Sur un des indices (la Babinais) les résultats (dosage de l'or) d'un test portant sur des prélèvements géochimiques en fond de vallon (10 éch./km^2) et en sols et bed-rock, montrent une bonne concordance avec les concentrations en or obtenues par voie gravimétrique à partir de ces mêmes prélèvements. Les éléments Au et As et plus accessoirement Sb, W, Pb restent les meilleurs traceurs de ce type de minéralisation ; on remarque ainsi que dans un tel contexte morphoclimatique, la recherche de structures aurifères par profils de géochimie nécessite un resserrement à 10 m des prélèvements le long de ces profils ; par contre, la prospection éluvionnaire à plus large maille est très efficace pour circonscrire les zones potentielles.

- Dans le secteur de Mozé (Maine-et-Loire), les minéralisations Au-Sb recoupées par sondages (traversées métriques à plurimétriques de 3 à 10 g/t Au) exprimées sous forme d'un fin stockwerk quartzo-carbonaté à sulfures (stibine, pyrite, mispickel, etc ...) et or sont associées à un couloir de fracturation (shear-zone) qui affecte les formations schisto-grèseuses d'âge ordovicien-silurien.

Elles sont situées dans une région boisée au relief peu accentué, à forte couverture pédologique. Ce sont des anomalies régionales à Sb, As et Ba, mises en évidence par la couverture géochimique multiéléments (3 éch./km^2) associés à des concentrations alluvionnaires en or (densité d'un concentré par km^2) qui ont attiré l'attention sur ce secteur.

Le contrôle géochimique tactique pour Sb-Au de ces anomalies, puis leur suivi détaillé par géochimie au bed-rock à la maille de 50 x 50 m, ont permis de circonscrire sur le prospect de Mozé une anomalie Au-Sb-As d'extension pluri-hectométrique comportant 2 axes anomaux (de direction NE-SW et NW-SEE).

Dans le district aurifère de Loperec (Finistère), les minéralisations recoupées par sondage carotté (traversées métriques à bimétriques de 10 à 20 g/t de type "stratabound" comprenant (mispickel, pyrite, chalcopyrite, galène, gersdorffite, etc...) et or sont associées à des formations volcanosédimentaires et à des structures siliceuses de la base du Carbonifère. Elles sont situées dans une région au relief constrasté, bien drainée et à sols résiduels. La découverte de ces minéralisations, totalement inédites, découle également des mises en oeuvre successives des prospections alluvionnaire et géochimique.

En effet, les premiers indices minéralisés ont pu très rapidement être localisés par un resserrement, sur les zones alluvionnaires régionales à or, de la maille de prospection alluvionnaire-éluvionnaire (250 x 250 m). Le suivi géochimique à la maille 100 x 50 m à 100 x 10 m (avec prélèvements au bed-rock) a mis en évidence une anomalie Au, As (Sb-Li) de 2 km d'extension.

Ces différents exemples de découverte de concentrations aurifères constituent ainsi une bonne illustration de la complémentarité des approches alluvionnaires-éluvionnaires et de la prospection géochimique selon l'échelle de l'exploration et du degré des connaissances acquises.

Ces techniques, associées naturellement à d'autres approches (synthèses géologiques prévisionnelles, étude des faciès aurifères, études minéralogiques et morphoscopiques, contrôles géophysiques, tranchées) ont permis d'aboutir rapidement à la sélection de nouveaux districts et à la découverte de nombreux indices aurifères.

Soulignons enfin que l'étude minéralogique et morphoscopique à la loupe binoculaire des minéraux lourds a de même permis d'appréhender, à un stade précoce de l'exploration, la granulométrie de l'or primaire, sa morphologie et la paragenèse des minéraux associés, paramètres autorisant un premier diagnostic sur la typologie des concentrations aurifères recherchées.

Thème 3 : EXPLORATION GEOCHIMIQUE EN MILIEU TROPICAL
Topic 3 : GEOCHEMICAL EXPLORATION IN TROPICAL TERRAINS

Geochemical Exploration models in tropical terrains.

C.R.M. Butt
H. Zeegers

An understanding of the geochemical environment is essential for the efficient application of geochemical surveys, whether at regional or at local scales.Although geological, geomorphological and environmental conditions are different for each location, so that the geochemical response to mineralization is always unique in some aspects, many similarities in dispersion characteristics are nevertheless present over extensive regions.

These characteristics can be summarized in the form of geochemical exploration models that illustrate the nature of the surface expression of mineralization. Ideally, it should be possible to use such models predictively when planning surveys, to anticipate mechanisms of dispersion, select appropriate sample media and estimate the nature and significance of anomalies.

The geochemical expression of mineralization in any environment is the product of the chemical and physical processes of dispersion - essentially the same processes as those of weathering, soil formation and landscape development. Climate is an independent factor in determining the nature of these processes and may become dominant if it remain unchanged over long periods of time. Thus soil characteristics of a climate may develop in 10^2 - 10^5 years and landscapes in 10^7 years.

However, climates have changed frequently and often quite profundly within these time scales, particularly since the mid-Tertiary, so that relic landforms and regolith material are present. In general, only the more recent, extreme or longer established climatic regimes leave relics of geochemical significance.

Whereas temperate and high latitude regions are dominated by the effects of Pleistocene glaciation, the warmer lower latitudes have regoliths and associated landforms related to past (or continuing) periods of deep weathering and lateritization under seasonal tropical conditions. The older, inherited regoliths are important not only because of dispersion associated with their development, but also because of the effect they have on currently active processes.

Models must therefore describe the genesis and total geochemistry of the landscape to account for dispersion related to these relic features as well as to active processes.

Models based on the preservation or alteration of characteristics of pre-existing deeply weathered terrains apply particularly to the region between latitudes 35°N and 35°S, although similar features have been observed at much higher latitudes, in places beneath glacial overburden. These regions were subjected to seasonally humid tropical climates, resulting is an intensely weathering and leached regolith (including laterite) and more or less marked planation of the landscape. Such conditions were probably widespread during the period from the Cretaceous or earlier until the mid-Tertiary, and subsequently contracted to the present near equatorial conditions.

Although modified under the influence of more recent climatic and tectonic changes, many geomorphic and geochemical characteristics of this early period have been preserved, partly because of the armouring effect of duricrusts.

The proposed model systems are based on the presence of relics of former landscape and associated weathering profiles (including lateritic regoliths) and the effects (if any) of later physical and chemical modifications. The models are classified (table 1) according to :

1. the present climate, which governs active dispersion processes and is mostly reponsible for the differenciation of the upper soil horizons :
2. the degree of preservation of the pre-existing profiles - i.e. wether complete or partly truncated, which defines the parent material of residual soils ;

3. chemical changes to the pre-existing profile. e.g. further leaching, cementation by silica or carbonates ;

4. the presence and nature of the overburden.

This subdivision is, of course, very simplistic, for where there are been frequent climatic and tectonic changes. Nevertheless, it provides a framework that enables valid comparisons to be made between terrains that are now in quite different climatic zones but that have important geochemical similarities. For example, the conditions that face the exploration geochemist in Western Australia (annual rainfull 200-300 mm) avec very similar to those prevailing in South Mali (rainfall 1200 mm), just because both regions are linked by their dependance on former lateritic weathering episodes.

The geochemical response is most complex where a fully preserved pre-existing lateritic weathering profile has been affected by further deep weathering under a very humid climatic regime. In such a situation, the different leaching stages have additing effects, so that the final result can be a strong impoverishment of most of the geochemical pathfinders in the different horizons of the current profile.

Table 1 - Classification of models in tropicaly weathered terrains

Present climate : Savanna (Seasonally humid)
Warm arid
Rainforest (humid)

Modifications to pre-existing profile within each climatic zone :

Pre-existing profile	Recent leaching	Recent accumulation or neoformation	Overburden
A. Mostly preserved	0. None	0. None	0. None
B. Partly truncated	1. Low	Al : Al-silicates oxides	1. In situ
C. Fully truncated	2. Moderate	Ca : calcrete	2. Transported
	3. Strong	Fe : Fe-oxide	
		Si : silica	
		Sm : smectite	

Examples : A 0 0 (0) : outcropping lateritic cuirasse
B0 Ca (2) : truncated with pedogenic calcrete and transported overburden

Geochemical dispersion of gold and associated trace elements in a lateritic profile in eastern Cameroon.

Ph. Freyssinet
A. Edimo
P. Lecomte
J. Vairon

In lateritic weathering profiles, the behaviour of trace elements is rather difficult to forecast and may significantly vary from one element to the other. As this behaviour directly controls the formation of the secondary geochemical dispersion halo over mineralization, it has a dramatic influence on the effectiveness of geochemical techniques in such environments.

Studying the dispersion of pathfinder elements in the weathering profile is of course easier in mineralized environments where several "uncommon" elements show rather high concentrations which may be detected even if strongly subdued by weathering effects.

Such a situation was recorded in the Batouri region, in eastern Cameroon, where a regional stream-sediment and heavy concentrate survey revealed gold mineralization, characterized by very high contents of several elements such as As, Bi, Mo, W, Pb and Ag. The dispersion of gold and associated elements is studied in detail from the fresh ore (deep drilling samples) soil and stream-sediment samples, taken at some distance from the mineralization.

Local geology includes Proterozoic (Birrimian) volcanosediments intruded by a quartz-monzonite stock. The auriferous mineralization seems to be controlled by a silicified structure parallel to the bedding, with a 45° dip.

In relation with a deep lateritic-type weathering, fresh outcrops are rather rare, except a few quartz structures. The idealized weathering profile can be described as follows, from bottom to top :

- saprolite, mostly made up of kaolinite, iron oxi-hydroxides and few primary residual minerals such as phyllites or quartz. Its thickness is about 25 metres, and well preserved primary structures are observed ;

- overlying mottled clay zone where Fe_2O_3 contents are rather high (12 to 20 %) ; thickness varies from 0.5 to 2 m. The upper part of the horizon may be indurated by Fe-oxides and form what could be considered as a duricrust, generally lacking on top of the silicified auriferous structure.

- on top, a reddish ferralitic horizon with iron oxides nodules of some 0.5 to 3 m thick, resulting from the indurated horizon degradation.

This study is based on ICP multielement analyses and AAS gold determinations of 216 samples consisting of :

- 83 drill hole samples, collected in the saprolite or in the fresh bedrock between 0 and 50 m depth ;
- 15 auger drilling ; samples collected in the saprolite at an average depth of 7 m ;
- 77 trench samples collected in the mottled clay zone ;
- 39 soil samples (100 m x 100 m sampling grid) ;
- 2 stream-sediment samples from the initial regional geochemical survey.

In depth, within the non or little weathered bedrock, the mineralizations are characterized by the following elements : Au (1-10 g/t), Ag (1-50 ppm), As (100-2000 ppm), Bi (10-500 ppm), Mo (10-100 ppm), Pb (200-2000 ppm) and W (50-1000 ppm).

In the saprolite, the geochemical signature of the mineralization is modified in such a way that Ag, Bi and Mo are almost completely leached out. On the contrary, all the other elements still show high anomalous values.

In the mottled clay zone, some enrichment is observed for Au, As and Mo in close relationship with the high Fe values themselves related to the laterization process. The other elements, such as Pb and W, are severely leached with regards to their contents in the sparolite.

In soil samples, extremely low contents are observed for most of the elements but concentrations of gold and pathfinders are still high enough to be considered as definetely anomalous and to be used to roughly delineate the extension of the mineralized structure.

In stream-sediment samples collected at about 0.5 km from the mineralization, Pb is the only element to show anomalous values.

This illustrates the progressive decay of the geochemical signature of a gold-bearing structure, from fresh rock to surficial soil and distal stream sediment. Moreover, an attempt was made to assess the size of the geochemical dispersion halo in the different horizons of the weathering profile and of the main key elements. Results may be expressed as a "mobility scale", with : Ag As Au Pb Mo W Bi. The position of the different elements on that scale is very likely related to their dependance on hydromorphic dispersion processes.

A better understanding of geochemical dispersion processes in lateritic environments may be helpful in selecting pathfinder elements to be used at different scales of exploration and in different sampling media when prospecting for gold mineralization in the bedrock.

Influence of calcrete formation on Pb-Zn anomalies in soils of the Bou Grine area (Tunisia). Relevance to geochemical prospecting

A. Guedria
I. Trichet
E. Wilhelm

Important Zn-Pb mineralisation, hosted by carbonates and shales, was recently discovered in the Bou-Grine area, Central Tunisia. These discoveries result mainly from geochemical soil prospecting which faced a fundamental difficulty due to calcrete horizons within the soil profiles. The problem was to estimate the consequence of the development of such calcretes on the anomalous zones previously existing within the pedologic formations.

The pedological, petrographical, mineralogical and geochemical analyses of non to highly calcreted soil samples led to the following conclusions :

- the petrographical mechanism of calcretization is a progressive epigeny of pre-existing minerals by calcite during which the metals which were associated to these minerals are destabilized and may be leached out of the profiles,

- these destabilization and leaching are most efficient when the metals are associated with fine-grained and poorly cristallized minerals (iron oxides in the case of the studied soils), and slower for metals associated with metal-rich minerals (sulfides and silicates),

- from a quantitative point of view, the elimination out of the profiles reached, in average in the Bou-Grine area, 64 % of Pb and 37 % of Zn initially associated with the horizons before calcrete development.

In the now existing calcrete horizons, the total amount of Pb and 95 % of Zn are assumed to be hosted in calcite, at contents close to 600 ppm for Pb and 3300 ppm for Zn. Other metallic elements (Ni, Co, Sr, Cd, Mn) are also associated with calcite.

The variety of profiles encountered in the Bou-Grine area gives good evidence of the role of the structure and petrography of the mother-rocks of soils on the morphology of the calcreted bodies within the profiles : the more angularly-dipping the strata and the more permeable the mother-rock, the thicker and the more facies-varied the calcretes.

Regarding the geochemical prospection methodology in such areas, the approach will depend upon the relative depths of the previous anomalous zones and of the calcretes within the profiles :

- if the calcretes develop under or above the anomalous horizons, the anomalous concentrations can be detected through conventional geochemical methods applied either to superficial or deep horizons in the profiles,

- if the calcretes develop in anomalous zones, the contrasts between such zones and non-anomalous adjacent ones has decreased in any case and the possibility of delineating the anomalous zones lies essentially upon the age and the intensity of the calcrete development, the greater the age or the intensity the lower the metal content and the poorer the accuracy of the result.

The erosion of horizons lying upon the calcrete bodies being facilitated by the presence of such crusts, the development of calcretes in profiles turns also out, through such a mechanism, to be a factor of loosing geochemical information on the localization of anomalies.

Gold dispersion and size fraction distribution in a tropical rain forest weathering profile at Dondo-Mobi, Gabon.

P. Lecomte
F. Colin

At Dondo Mobi (Gabon) gold from a rather narrow bedrock mineralization strongly mushrooms in the different horizons of the weathering profile. The observed dispersion pattern is in some way anisotropic, with a strong enlargement in both the upper (H1) and glebular* intermediate (H2) horizons.

The distribution of gold is studied in the different horizons of the weathering profiles and in the different grain-size fractions of the sampled materials. Sampling was carried out in three pits located upslope (pit 1), above pit 2 and downslope (pit 3) of the mineralization.

Initially, five size fractions were considered : < 63 µm, 63-125 µm, 125-250 µm, 250-500 µm and ≫ 500 µm. Subsequently, the three fractions between 63 and 500 µm were merged because of their very low average gold content. Gold was analysed by AAS, with a detection limit of 5 ppb.

A careful estimation of amounts of gold distributed amongst the different grain size fractions was made, taking into account not only the gold contents in the size fractions but also density variation between the bedrock and the weathered horizons as well as modifications in the grain size composition from one horizon to the other.

The overall calculations show that variations in grain size composition amongst the different horizons cannot alone explain the Au content variation observed.

The gold analytical data and calculations show a clear enrichment in the fine (< 63 µm) size fraction of the H1 upper horizon if compared with the same size fraction from the H2 and H3 horizons. If the total gold content is 1 g/t or more, 40 to 80 % of the total gold is present in the ⩽ 63 µm fraction and thus 20 to 60 % in the medium to coarse fractions. In samples with lower gold contents, for instance at the outer limits of the dispersion mushroom or in the H2 or H3 horizons away from the mineralization, the proportion of gold in the fine fraction may be as high as 90-100 %.

The coarse size fraction (> 500 µm) is also proved to be enriched in gold in the upper horizon of the weathering profile, probably in relation with some kind of nugget formation process even if some relictual primary gold particles can also persist to the surface.

Therefore, the anomalous gold secondary dispersion halo is mostly made up of fine gold. By reference with the rather coarse gold grain size observed in the fresh ore (around 55 % between 63 and 500 µm and 40 % in the ≫ 500 µm fraction), most of the gold present in the dispersion halo, proceeds from dissolution of residual coarse gold grains followed by hydromorphic dispersion and precipitation or fixation as secondary finer gold.

As far as exploration is concerned, the geochemical techniques are suitable for prospecting for gold in tropical rain forest weathering profile, where a significant and well-contrasted secondary dispersion halo facilitates the detection of even narrow mineralization by using a rather large sampling interval.

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* Relict-products of lateritic evolution (Brewer R., 1964 : Fabric and minerals of soils - J. Wiley and Sons, N.Y., 470 p).

Dispersion of metals from the Edwards Creek gossan, Arunta complex (arid-zone) central Australia.

B. Murrell

A siliceous haematite gossan in the catchment of Edwards Creek is discontinuous over a 400 m strike length and is associated with marble in granulites. The base of oxidation is 70 m below the gossan and about 45 m below the drainage base. An intersection near the base of the oxidised zone gave 13.6m% Cu plus 0.6m% Pb under the biggest gossan expression ; in the primary ore zone under another gossan 100 m to the south, 2.8m% Cu plus 2.3m% Pb was intersected.

Dispersion of metals into the stream sediments occurs in two ways :

- mechanical transport of fragmental material from the gossan ;
- mechanical transport of the saprolite clays which recieved a metal halo, overprinted during weathering of the primary mineralization.

The signature in the stream sediments is thus a dispersion of a dispersion. Leaching of the stream sediments continues as drainage is effluent from the channel to the groundwater. Analysis of the -180 micron fraction of the stream sediment could only positively identify the weathered mineralization at a distance of 100 m from the gossan. Analysis of the clay fraction could positively identify the mineralization within two 1 km square catchments (the gossan formed the drainage divide). Both results show that this mineralization would remain undetected in the standard Australian regional sampling pattern because of the deeply leached profile.

Some implication of the lateritic weathering on the geochemical prospecting. Two Brazilian examples.

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F. Soubies
P. Audry
F. Espourteille

Two brazilian cases in tropical areas show that sampling methodology and statistical treatment of data must be adapted to pedological realities of the prospected environments. In fact, this approach gives a better quality of the geochemical halo of the bed rock and makes their interpretation easy.

The two areas studied, "Val do Paramirim" (West of Bahia) and "Chapada grande" (Center of Goias), on Precambrian metamorphic basements, correspond in one case to a Pb-Zn occurrence, in another case to a Cu occurrence. In each case petrological and geochemical studies were carried out on different weathering horizons of typical slope-sequences. In "Val do Paramirim", under semi-arid conditions, lateritic soils with underlying stone-line change laterally into sandy leached soils. In "Chapada Grande", a partially eroded iron crust plateau, in semi-humid tropical climate, is investigated.

The main results of these studies are :

1) In both cases, petrological and geochemical data show a good lithodependence, from the bottom to the top, of all weathering materials and specially of the iron crust and the stone-line. Therefore, superficial geochemical halos are "deep-seated".

2a) In the "Paramirim" sequence, the lateral leaching of iron and clays accompanies both a strong diminution in the Pb-Zn-Cu content and a complete modification of the correlations among these elements (in lateritic soils Cu and Zn are strongly correlated while Pb is independent, although in sandy soils the correlation among this three elements is slight). False lead anomalies can also occur because of its strong tendency to concentration in hydromorphic manganesiferous and ferruginous concentrations frequently formed in slopes and level with stone line.

2b) In "Chapada" sequence, all the profiles show an upwards diminution in the total Cu content from the fresh rock to the surface. In the soft cover of the iron crusts, a strong decrease of the copper content is observed. In the upper part of the weathering profile several investigations (select chemical dissolution, microprobe analysis...) show a strong link between Fe-oxihydroxides and Cu. This fact explains, in the soft cover of the crust, a higher Cu content in the ferruginous nodules, inherited from the iron crust, than those is their quartz-clayey matrix.

3) With respect to geochemical prospecting, the study shows that sampling and data interpretation methodologies must be everytime adapted to the soil types of the prospected environments : in the "Chapada" prospect and in the case of the soil on iron crust, it is better to collect and analyse coarse fractions (> 2 mm) formed by iron nodules inherited from the autochtonous iron crust, in another cases the fine fraction (< 0.1 mm) may be prefered. In any case, the grouping of data by classes of soils, for example, according to surface features (colour, presence or not of coarse elements, position in the landscape etc...) is highly recommendable before any statistical treatment of data. Therefore, in tropical geochemical prospecting, the knowledge of the pedogenesis appears to have as much importance as the one of the bedrock.

Gold prospecting in the central pediplain of the Precambrian shield, Kingdom of Saudi Arabia.

I. Salpeteur
H. Sabir

A reassessment of the most recently published geomorphological data which discusses the erosional history of the Precambrian shield of Saudi Arabia highlights some new concepts on the mobility of gold in the recent residual soil cover.

The lack of humic and organic complexes in arid climates hinders gold dissolution from primary sources where native gold is very fine or included in sulfide and telluride networks. The main dispersion of gold in the present climatic conditions is essentially mechanical and the secondary reprecipitation is probably a very minor process, even if it was more active during past and more humid climatic periods.

Several orientation studies have been performed by the DMMR-BRGM mission between 1982 and 1986 around eight gold prospects of the central pediplain. some of them unworked in ancient times. This operation aimed at checking the secondary dispersion of gold in soil and wadi sediments.

Soil tests included sampling of the three pedological horizons in the vicinity (10 - 20 m) of the gold source, and wadi tests concerned two pits located between 100 - 200 m and 500 - 1000 m downstream with selection of each alluvial layer. Each sample was then sieved in seven fractions (from 3.15 mm to less than 0.080 mm) and analyzed for gold by A.A. after MIBK extraction and 60 % repeat analysis made by fire assay - N.A.A..

The following results were obtained :

- gold has a more homogeneous distribution and shows more contrasted values in the finest fraction :
- when approaching an unworked gold source, gold is evenly distributed in all grain size fractions ;
- further downstream (100-1000 m) the overall gold contents rapidly decrease (so that its detection is strongly dependent on analytical sensitivity and the finest size fractions show the highest contents ;
- in present braided stream system, the upper gravelly layer below the eolian sandy cover or heavy mineral concentrate at the top of the bankets will provide a satisfactory sampling medium ;
- there is no gravity reconcentration of gold at the wadi-sediment/bed rock interface in wide channels ;
- dilution and heterogeneity in the geochemical response increases with flat width ;
- hand panning gives very poor results owing to the loss of flour gold particles and the eolian clay loading of the alluvial materials, and is very costly.

All these results led to recommend the following procedures for porspecting for gold is the conditions of the Arabian shield, and in areas previously selected according to different criteria :

- if the drainage pattern is well marked, sampling the gravelly upper layer of the alluvial material and gold determination by NAA in the finest size fraction (1 sample/km^2 in average). Analyzing the coarse size fraction (-3.15 +1 mm) by a multielement technique is also strongly recommended ;
- if the drainage is poorly developped or lacking, the top layer of "soil" should be sampled at a regular interval (average density 4 samples/km^2) and analyzed as the wadi samples, as concerns the size fractions and the elements to by determined.

The follow up work to be carried out to control the anomalies resulting from the regional survey will be adapted to each particular environment, taking into account the geological and morphological characteristics.

The implication to exploration of chalcophile corridors in the Archaean Vilgarn Block, Western Australia, as revealed by laterite geochemistry.

R.E. Smith
R.D. Birrell
J. Brigden

The regional distribution of the chalcophile (or partly chalcophile) elements As, Sb, Bi, Mo, Ag, Sn, and W in laterite over the Archaean Yilgarn Block of Western Australia is dominated by elongated trends within which chalcophile abundances are relatively high compared with general backgrounds. As seen from orientation studies laterite geochemistry in W.A. generally provides an imprint of geochemical patterns observed in bedrock, albeit with some degree of dispersion. This imprint relationship and other evidence discussed below leads to the conclusion that these chalcophile trends in the lateritic duricrust materials imply the existence of chalcophile geochemical provinces in bedrock and mark out the spatial distribution of such provinces across the Precambrian craton.

The chalcophile trends revealed by regional multi-element laterite geochemistry are typically 15 km to 30 km wide and 50 km to 100 km long, some extending to 150 km. There appears to be a broadly coincident spatial relationship between the chalcophile trends and the distribution of a variety of ore types including gold and base metal sulphide deposits. The name "chalcophile corridor" is herein proposed because the trends appear to be the geochemical expression of the gold exploration corridors of Fehlberg and Hallberg (1983). So far some forteen chalcophile corridors have been recognized in the regional laterite geochemistry arising from this study.

Systematic application of multi-element laterite geochemistry to exploration in Australia was demonstrated to be feasible in the Golden Grove massive sulphide district of Western Australia (Smith et al., 1979 ; Smith and Perdrix, 1983). Subsequent laterite dispersion studies about rare metal pegmatites of the Greenbushes mineral field (Smith et al. 1985) resulted in the suggestion that broadly spaceo laterite sampling, for example at 3 km - spacing, may be feasible as a reconnaissance exploration method for a variety of ore types.

A collaborative research project at CSIRO in Perth commenced in 1980, sponsored by Greenbushes Tin Ltd, and in 1983 by St. Joe Minerals in conjunction with Greenbushes. The main research aim of the project was to test the application of broadly spaced laterite geochemistry in reconnaissance exploration for a variety of ore types including gold and base metal deposits, with the focus on selected parts of the Yilgarn Block of Western Australia. This approach has been validated, a satisfying result stemming from the research being the discovery by laterite geochemistry of the Johnson Range Gold deposits by Greenbushes and St. Joe. A Further example is the recognition of chalcophile corridors, the topic of this paper. The findings reported here are based on 3800 samples of lateritic duricrust material, analysed for 25 to 35 elements, arising from the collaboration research project from areas totalling 30,000 km2 scattered widely over the Yilgarn Block.

The prominent chalcophile corridor centred on Warriedar will be discussed as a specific example. Recognized from its dominant As + Sb anomalous laterite geochemistry, the corridor extends in excess of 100 km and ranges from 5 km to 40 km in width. It includes several significant ore deposits, numerous minor gold deposits or prospects and many as yet unexplained geochemical anomalies in the lateritic materials. Towards its northern end the As, Sb, Bi, In, Mo, Sn and Au laterite anomalies arising from the Gossan Hill and Scuddles massive sulphide deposits lie within the corridor. Towards the centre of the corridor the Mt. Mulgine Mo, W, (Au) deposit, located at the contact of a leucogranite stock, has given rise to an anomalous association of Cu, As, (Bi), Mo, Ag, Sn and W. At its southern end the Mt. Gibson lateritic Au deposit lies within a broad As, Sb, Ag anomaly with locally anomalous Ge and Au.

Elsewhere chalcophile corridors are associated with the Boddington Gold deposit where the corridor has an As, Sb, Bi, Mo, Sn, W, Au association, at the Greenbushes rare metal pegmatite field where the corridor has an association of As, Sb, (Bi), Sn, and at the Kalgoorlie Golden Mile where the association is As, Sb, (Sn) and Au.

Some of the chalcophile corridors appear to spatially link with major faults and regional shear zones, for example at the Keith-Kilkenny Tectonic Zone of Hallberg (1985) and Donnybrook-Bridgetown shear zone at Greenbushes (Partington and Harris, 1986). Whether the chalcophile associations in laterite are reflecting hydrothermal processes of rock alteration and mineralization along shear zones, or activity at Archaean volcanic centres or intrusions is presently an open question. Much more research needs to be directed at identifying in bedrock the specific rock types/structural associations that give rise to the anomalous chalcophile elements.

Although largely at the research stage to concept of chalcophile corridors appears to have important implications in mineral exploration because of the possibility of delineating the most prospective terrain at the reconnaissance.

REFERENCES :

FEHLBERG B. and HALLBERG J.A. (1983) - Gold discovery and production map, Eastern Goldfields Region, Western Australia, Minplex Resources, Belmont, W.A.

HALLBERG J.A. (1975) - Geology and mineral deposits of the Laverton Leonora area, Hesperian Press.

PARTINGTON G. and HARRIS L.B. (1986) - Sinistral transcurrent shear zones along the western margin of the Yilgarn Block, Western Australia Abstract, Geological Society of Australia, W.A. Div. Monthly Notes, n° 243.

SMITH R.E., MOESKOPS P.G. and NICKEL E.H. (1979) - Multi-element geochemistry at the Golden Grove Cu-Zn-Pb-Ag deposit. In University of W.A. Extension Service Publication n° 4, p. 30-41.

SMITH R.E. and PERDRIX J.L. (1983) - Pisolitic laterite geochemistry in the Golden Gove massive sulphide district, Western Australia, J. Geochem. Explor. 18, p. 131-164.

SMITH R.E., PERDRIX J.L. and DAVIS J.M. (1985) - Dispersion into pisolitic laterite from the Greenbushes mineralized Sn-Ta pegmatite system, Western Australia. Abstract Volume, p. 85, 11th International Geochemical Exploration Symposium, Toronto.

Tropical weathering control of Ni, Cu, Co and PGE distribution at the O'TOOLE deposit, Minas Gerais, Brazil.

P. Taufen
M.L. Marchetto

Located in the Minas Gerais southern plateau morphological and structural province, the O'Toole nickel sulphide deposit is at present within a humid tropical climate characterized by mean annual temperatures of 19°C and rainfall of 1600 mm. The deposit itself comprises 5.3 million tons at 2.6 % Ni, 0.4 % Cu, 0.05 % Co, and 1.3 ppm combined platinum group elements (PGE). Tropical weathering of the vertically-dipping orebody has created gossan at surface, an oxidized capping to a depth of about 20 meters, and a zone of transition above fresh ore to about 70 meters depth. The weathering profile is shown to be similar mineralogically to the profiles at the Kambalda, mount Windarra, and Agnew Ni sulphide deposits, differing in depth extents of the distinctive mineral zones. The mineralogically distinctive zones in the O'Toole deposit weathering profile exhibit geochemically distinctive enrichments and depletions of various elements based on their respective geochemical mobilities in this particular environment. The work presented characterizes the geochemical behavior of Ni, Cu, Co, and PGE in the weathering of the O'Toole deposit.

From combined geochemical and petrographic study of fresh ore, it was possible to characterize the mineral forms of both base metals and platinum group metals and to establish consistent concentration relationships among these metals using correlation coefficients and simple linear regression calculations. Significantly, a close correspondence was observed among all of the elements considered with the lone exception of Cu. Even more significantly, the geochemically highly immobile element iridium exhibited high correlation coefficients with a number of elements, with coefficients above 0.8 for Pt, Pd and above 0.9 for Ni, Co, Rh, and Ru (copper correlated poorly with iridium in fresh ore). Furthermore, iridium is shown to be a useful independent variable predictor of the dependent variable elements Ni, Co, Pt, Pd, Rh, and Ru in unweathered mineralization based on scattergram plots. This finding provides a means to estimate original concentrations of geochemically mobile elements in weathered rocks based on their established linear relationships with iridium. Linear regression equations were calculated relating Ir concentrations to Ni, Co, Pt, Pd, Rh and Ru concentrations in fresh ore.

These fresh ore observations were used to evaluate relative enrichments and depletions of elements in transition zone ore and in the oxidized capping. This evaluation was achieved by comparing actual element concentrations of Ni, Co, Pt, Pd, Rh, and Ru to concentrations predicted form analyses of iridium, the element most chemically refractory and geochemically immobile of the element group studied.

Based on the data presented, conclusions are reached regarding the weathering behavior and relative mobilities of Ni, Co, Pt, Pd, Rh, and Ru during the oxidation and leaching associated with tropical weathering of this Ni sulphide deposit.

Thème 4 : L'OR EN MILIEU LATERITIQUE
Topic 4 : GOLD IN LATERITIC ENVIRONMENT

Geochemistry and mineralogy of laterites in the Sula Mountains greenstone belt, Lake Sonfon gold district. Sierra Leone.

T. Davies
G. Friedrich
A. Wiechowski

Geochemical and mineralogical investigations have been carried out on laterite profiles developed in the Lake Sonfon gold district of northern Sierra Leone. The area is underlain principally by Archaean metavolcanics and constitutes part of the Sula Mountains greenstone belt which is mineralized in gold. Extensive lateritization has affected the rocks of this region resulting in a profile which from bottom to top consists typically of a decomposed bedrock zone, a pisolitic laterite layer and a duricrust layer. Both the pisolitic laterite layers and the duricrust layers are sometimes punctuated by lenses of ironstones containing high amounts of copper, zinc, nickel, cobalt and cerium. Gold occurs as small grains within the heavy mineral fraction recovered from the decomposed rock zones and pisolitic layers of the profiles and also in gravels of streams draining the area. The mineralogy of the duricrust and pisolitic layers is dominated by goethite, gibbsite and quartz with minor amounts (< 5 % by volume) of ilmenite, magnetite, haematite, rutile and kaolinite. The kaolinite content increases towards the decomposed rock zone, where talc, vermiculite and other layer lattice silicates become abundant. The heavy mineral fraction of stream sediments is composed essentially of ilmenite, magnetite, haematite and traces of rutile, zircon, tourmaline and gold. The gold grains are often characterized by a 10-200 -wide rim having a much lower content of silver (0.3 wt.% or lower) than the grain interior (about 5 wt.% on average). Dissolution effects are also observed on the grain surfaces. It is considered that gold derived from the amphibolite parent rock is dissolved, transported and redeposited during lateritization.

The duricrust cover of the laterite profiles is characterized by high Fe_2O_3 (ca. 60 wt.%) and Al_2O_3 (ca. 32 wt.%) and low SiO_2 (ca. 9 wt.%). In comparison, the pisolitic layer has a higher SiO_2 (ca. 18 wt.%) as well as a slightly higher Al_2O_3 (ca. 34 wt.%). Lateritic weathering has resulted in the removal of CaO, Na_2O, MgO and SiO_2 with relative enrichment of Fe_2O_3 and Al_2O_3. The contents of copper, zinc and cobalt in the auriferous horizons of the laterite profiles appear to correlate well with their contents in the adjacent gold-bearing stream sediments. The significance of these observations are discussed in relation to the origin of the lateritic gold and the role of the associated trace elements as indicators of the mineralization.

Discovery of the Loulo gold deposit (Mali).

A. Dommanget
H. Traore
H. Zeegers

In the Kenieba region (Southwest Mali), small alluvial or eluvial gold occurrences have been exploited by local miners for centuries. In 1978. an exploration joint venture (French Bureau de Recherches Géologiques et Minières and the Direction Nationale de la Géologie et des Mines du Mali) started a systematic regional survey of that promising auriferous district. The main result of that survey is the discovery of the Loulo gold deposit. At Loulo, the mineralization is strictly confined to a layer of tourmaline sandstones, of some 10 m width, within Birrimian (Proterozoic) sediments (shales and sandstones).

The first stage of exploration was carried out in 1978 in an area of some 2000 km^2, covering most of the ancient and present local gold mining works. Soil geochemical survey was preferred to stream-sediment sampling, because of a very smoothed topography and a poorly developed drainage pattern. Sampling was performed on a 1600 m x 500 m grid ; some 3200 samples were collected at a depth varying between 0 and 40 cm. Soil situation was very different from one site to the other, ranging from outcropping hard iron crust to soft kaolinitic material. The samples were prepared in two different ways : for gold analysis, they were sieved to 125 microns, with recovery of the fine fraction. For multielement analysis by Direct Reading Spectrometry the paramagnetic fraction of the samples was separated within the 63-250 micron fraction.

As far as possible, geological information was collected during the survey, and used for ranking the gold geochemical anomalies, together with the results of the multielement analysis. Some 30 significant anomalies came out of that first step. Most of them were controlled by follow-up work in order to improve the preliminary ranking in terms of economic interest. This was achieved through a detailed soil geochemical sampling during which a geological sketch map was also prepared. In some favourable situations, very detailed information was obtained about the possible type of mineralized structure responsible for the geochemical anomaly : vein, stratabound, etc. Also, the possibility of "false" gold anomaly (contamination by old workings for instance) was investigated.

More especially, a gold anomaly (1 sample with 1200 ppb Au) from the regional survey, recorded as No. 26, contributed in evidencing a gold mineralization closely associated with a tourmaline sandstone bed. Subsequent eluvial and rock sampling (at the surface and by percussion drilling) showed gold grades of some g/t.

In 1982 a drilling campaign was conducted at Loulo. As a result, anomaly 26 was proved to correspond to a deposit with some 20 t of gold reserves, at a mean grade of 5 g/t, lying between 0 and 100 m depth. Downdip extension is still open. The mineralization is controlled by a quartz, carbonate and sulphide stockwork in a regionally distributed tourmaline-sandstone bed.

It should be noted that the full exploration sequence, from the regional campaign to the feasibility survey was carried out in four field seasons.

Geochemical patterns associated with alteration at the Connemarra and Kathleen Au deposits, Western Australia.

A.J. Eggo
M.G. Doepel

The Connemarra and Kathleen Au deposits are situated in the Youanmi Archaean greenstone belt approximately 500 kilometres northeast of Perth, Western Australia. Gold mineralisation, which appears to be largely shear controlled, is hosted by altered felsic tuffaceous rocks, fractured quartz-eye tuff and subordinate intercalated banded iron-formation. Minor mineralisation is hosted by granite. Carbonate, sericite and disseminated pyrite are associated with the lodes. These alteration haloes are more extensive than the gold lodes themselves and serve to enlarge the exploration target. Outcrop in areas of known mineralisation is good. However, in prospective areas to the southeast outcrop is poor, but surficial deposits are generally less than 5 metres thick. Complete oxidation of the bedrock has occurred to a depth of about 60 metres.

Reverse circulation percussion drill cuttings from the oxidised zone developed over both deposits were subjectively assessed as to their visible degree of alteration. A sample was considered altered if it showed extensive sericitization, voids or limonitic pseudomorphs after sulphides, gossanous or vein quartz or fine iron-rich fractures. A coding system was devised which categorised each sample as representing altered, less strongly altered or unaltered rock. Although most rock types generally showed some degree of alteration in the Connemarra and Kathleen environments the coding system represented an effort to determine relative alteration features that could be utilized to predict proximity to mineralisation.

This paper presents the results of a study designed to geochemically characterise altered and unaltered lithologies from both deposits. Analysis of variance studies indicated that the elements As, Sb, Au, Cu, Y, W, Ba, Zr, Mn, V, Bi, Se, Ti and Ni report statistically significant differences between the type groups. However, no single element could effectively discriminate between the various populations, requiring that a multivariate approach be taken.

Stepwise discriminant analysis proved to be the most suitable technique and was applied to reduce the original suite of elements to an optimum group of pathfinder variables indicative of alteration accompagnying gold mineralisation in the Youanmi area. These optimum pathfinders represent the variables that most effectively differentiate altered rocks from unaltered rocks recognised at Connemarra and Kathleen. The quantitative and qualitative effect of the variables on the correct classification rate of the total population and the individual groups was investigated. The results show that the elements Sb, Zr, As, Ti, Cu, Mo, Bi, Co, Zn, V, W and Ag, in that order, are of major importance in the separation of altered from unaltered rocks at both mineralised areas.

The separation among the groups in 12 element space can be portrayed in two dimensions by a plot of canonical variates I and II. The two unaltered groups are well separated whereas the two altered groups from each deposit overlap slightly indicating common multi-element characteristics. The two altered groups contain highest mean concentrations of Au, Zn, Cu, Ag, Co, Zr, Pb, As, Bi, Sb, Ba and W. Therefore, a sample enriched in all or most of these pathfinder elements will have a high probability of falling within the alteration envelope which includes the Connemarra and Kathleen gold deposits.

The two altered groups were combined and a simple discriminant function calculated that distinguishes altered rocks from unaltered rocks. The discriminant equation involved the elements Au, Cu, Zn, Co, As, Sb, Ti and Zr. A calculated F-value of 142.3 for testing the equality of individual multivariate group-means for the above elements is highly significant at the 99 % level. Overall correct classification rate is 94.3 % with rates of 91.5 % and 96.4 % for altered and unaltered lithologies respectively. Side-byside histograms of discriminant scores for the two groups show that the efficiency of the discriminant function in separating the two categories is far higher than for any single element. Variability is considerably reduced and multivariate normality has been achieved.

The calculated discriminant function has been used to seek the alteration signature in geochemical data from regional drilling. For a sample of unknown affinities, geochemical analysis of Au, Cu, Zn, Co, As, Sb, Ti and Zr will permit the calculation of the discriminant score. This score will be negative for an unaltered rock and positive for an altered rock associated with Au mineralisation. Plans of discriminant scores indicated anomalous zones which have been recommended for follow-up exploration.

In the Western Australian environment, where much of the bedrock is deeply weathered or capped by thick ferruginous lateritic overburden, the diagnostic mineralogical alteration zones described for many Archaean gold deposits in Canada and Australia (Harris, 1986 ; Phillips, 1985, 1986) are generally obscured. The use of geochemistry to quantitatively assess alteration patterns in the weathered environment overcomes this limitation. If follow-up work proves successful, the above approach will be a useful exploration tool for detecting buried gold deposits blind to geophysical and conventional univariate geochemical interpretation techniques.

REFERENCES :

HARRIS D.C. (1986) - The minerals in the main Hemlo gold deposit, Ontario. in Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 49-54.

PHILLIPS G.N. (1985) - Archaean gold deposits of Australia. Economic Geology Research Unit, University of Witwatersrand, Information Circular n° 175.

PHILLIPS, G.N., (1986) - Geology and alteration in the Golden Mile, Kalgoorlie. Econ. Geol. Vol. 81, 1986, p. 779-808.

Morphoscopy and geochemistry of gold in a lateritic profile at Kangaba (southern Mali).

Ph. Freyssinet
H. Zeegers

Gold is now a key target for exploration in tropical environments where, unfortunately, the bedrock mineralization is often overlain and concealed by a thick lateritic weathering mantle. The behaviour of gold within such profiles is of direct concern for mineral exploration. In this paper, the evolution of shape and geochemistry of gold nuggets sampled in different horizons is studied. The samples were collected in the Kangaba area, southern Mali, where the climate is of Soudanian type.

At Kangaba, the laterites result from the weathering of Birrimian (Precambrian C) shales and volcano-sediments, where gold occurs within quartz veins and veinlets, with pyrite and arsenopyrite. The weathering profile is very thick (several tens of meters) and the following horizons may be distinguished, from base to top :

- the saprolite, mostly formed by kaolinite, iron oxi-hydroxides and rock-forming minerals. The rock textures such as schistosity and joints are preserved, and the thickness may be of some tens of meters ;

- the mottled clay zone, a few meters thick, with partially indurated iron stains and where the rock textures gradually disappear ;

- on top of the profile, the indurated "cuirasse", 3 to 10 meters thick, made of Fe and Al oxihydroxides nodules and kaolinite.

The quartz veins and veinlets are, of course, more resistant to weathering than the host rocks. Therefore, they are only partly dissolved in the mottled clay zone and disappear in the cuirasse. The sulphides associated with the gold mineralization are oxidized almost all along the weathering profile, and are pseudomorphed after geothite.

Pits were dug accross the lateritic profiles and 200 samples of about 40 kg each were collected. After grinding, some 500 gold flakes were recovered, observed under microscope and S.E.M., and classified into three categories according to their origin : quartz structures in the saprolite, clay horizons, cuirasse.

A statistical analysis of the shape of nuggets was made using different morphoscopic parameters characterizong the size, overall shape, roughness, brightness, bluntness and surface aspect. The results show a significant variation of size and shape of gold particles from the primary mineralization to the lateritic cuirasse.

The size (main axis) of flakes gradually decreases upwards in the weathering profile, from 600 µm in the quartz veins down to 320 µm in the clay horizons and 240 µm in the cuirasse.

The flakes collected in the quartz veins have been separated into two categories, according to a xenomorphic shape showing prints of the surrounding crystals or a fluffy form with jagged rims.

In clay horizons, gold flakes show the same shape as in the quartz veins, but blunting is commonly more important.

In the cuirasse horizon, the fluffy forms disappear, and rounded nuggets are predominant.

S.E.M. studies show that the roundness of flakes is due to chemical erosion. Numerous etching pits filled with a clay-ferruginous material were observed, as well as signs of secondary gold precipitation in relation with neoformed minerals. In this case gold crystallizes in pores, its size is generally smaller than 1 µm and three types of particles can be distinguished :

- microspherulites or membranes in the clay and ferruginous matrix ;
- dendrites developped at the surface of iron oxides ;
- secondary gold cortex around strongly blunted nuggets.

Electron microprobe analyses of polished sections show that flakes recovered in the primary mineralization contain 6 to 12 % Ag, whereas secondary gold is almost pure.

Lateritization weathering process is thus strong enough to mobilize moderately soluble metals such as gold. Corrosion and chemical bluntness are the first signs of the effect of weathering on the gold particles, and remobilization increases in the upper part of the profile, with a maximum in the cuirasse horizon. Dissolved gold may reprecipitate as microcrystals within the weathering products.

These processes of dissolution and reprecipitation are responsible for the dispersion of gold in lateritic weathering profiles and, more especially, in the upper cuirasse horizon. As concerns geochemical exploration, a rather wide secondary dispersion halo over gold mineralization may thus be expected where lateritic-type weathering occur.

Temporel variations in the trace element content of stream-sediments from the seasonally wet-dry tropics.

J. Ridgway
P.N. Dunkley

The climate of Zimbabwe is characterised by a dry season (May to November), with virtually no rainfalls, and a wet season with intermittent and heavy rainfalls. Two areas in Zimbabwe have been sampled several times during the period November 1983 to May 1986 and tested for evidence of seasonal variation in the trace element content of fine-fraction (-80 mesh) stream sediments. Rivers in these areas flow only after heavy rain in the wet season.

The Chikwizo area lies in northeastern Zimbabwe and is the location of a Pb anomaly derived from a sulphide-bearing vein in gneissic xenolithic granodiorite of late Archaean age. Minor amounts of galena, chalcopyrite, pyrrhotite, pyrite and malachite are found at the margins of the vein and in the wall rock. Seven sites downstream of the mineralization were sampled six times between November 1983 and July 1985.

At the Concession prospect in the Mazowe area north of Harare nine sites were sampled on nine occasions between November 1983 and May 1986. The anomalies here are in Zn, Ni and to a lesser extent Cu, and arise from a sequence of banded ironstones and ferruginous mudstones interstratified with rhyodacitic, andesitic and basaltic metavolcanic rocks of the Mazowe Greenstone Belt.

Initially six subsamples were taken at every site and each subsample was split to give a replicate. Random numbers were assigned to the subsamples and replicates before submission to the laboratories, where each was analysed by AAS for Cu, Pb, Zn, Co, Ni, Mn and Fe after separate acid digestions using cold dilute HCl, hot HCl and hot HNO_3, and by XRF for Ti, Fe, Mn, As, Ba, Co, Cr, Cu, Ni, Pb, Rb, Sr, V and Zn. The number of samples processed from each site was reduced later in the project after analysis of variance techniques had shown that differences between replicates and subsamples were not significant when compared with between site variation.

Significant variations between collections made at different times were found. These could not be attributed to laboratory or sampling errors and must be related to physical and chemical changes at the sample sites. Magnitudes of anomalies and background levels varied greatly with the time of collection and in some instances the anomaly became undetectable. The results have important implications for sampling and analytical strategies and the interpretation of geochemical data.

Geochemical signature (bedrock and saprolite) of gold mineralization and associated hydrothermal alteration at Dorlin, French Guyana.

G. Taylor
B. Coste
A. Lambert
H. Zeegers

The Dorlin gold prospect is located in central French Guyana, within a Proterozoic volcano-sedimentary belt where numerous old gold workings are known. Following a regional geochemical campaign carried out in 1975, several geochemical anomalies (Au in soil and stream sediment samples) were controlled by follow-up soil and saprolite (auger sampling) surveys. Since 1986, the operations are in hand of a BRGM-UTAH joint venture.

The prospect is composed of several strongly anomalous zones (for Au and associated elements) which came out from the auger survey and whose ranking was not easy. Indeed, weathering is intense at Dorlin, resulting in poor outcrop (and geological observation) conditions and possible remobilization and leaching of gold in the upper part of the weathering profile.

A deep drilling program was thus undertaken, along a profile perpendicular to the main saprolite Au anomaly. A carefull study of mineralized and barren samples (petrology, mineralogy, geochemistry -Au by AAS and 34 major and trace elements by ICP) showed that gold is mostly associated with sulphides (pyrite, arsenopyrite). These minerals are included in a complex hydrothermal assemblage, with chlorite, sericite, quartz and tourmaline.

Such a mineralogical composition results in a fairly contrasted geochemical signature in mineralized unweathered samples, with high contents of elements as K_2O, As, B, MgO ...

The evolution of that geochemical signature as weathering intensity increases (with decreasing sampling depth) was studied for two mineralized intersections from two drill holes.

In the first case, the key elements in fresh mineralized samples are MgO (3-6 %), K_2O (1-2 %), Fe_2O_3 (15-20 %) and As (500-1000 ppm). Near the surface (1 to 8 metres depth), in the saprolite, the main evolution to be noticed is a significant loss in MgO, indicating that chlorite is almost totally leached. Other minerals as sericite appear to be rather stable in the supergene conditions, as shown by the high K_2O contents in saprolite samples. Other elements as Fe_2O_3 from pyrite or As from arsenopyrite are probably associated, in the weathering zone, with secondary Fe-oxides (hematite, geothite).

The second studied mineralized section shows a quite different mineral association, with dominant tourmaline reflected in fresh and weathered samples by very high boron contents (several thousands of ppm) and relatively high MgO concentrations (up to 3 %).

So, each mineralization type is characterized by a different geochemical signature, which may be quite easily detected even in deeply weathered saprolite samples. Such samples are collected in an unexpensive way (by hand auger drilling) and, if analyzed for the required elements, may provide a significant basis for planning a further drilling program.

Thème 5 : PROSPECTION BIOGEOCHIMIQUE DES METAUX PRECIEUX
Topic 5 : BIOGEOCHEMICAL EXPLORATION FOR PRECIOUS METALS

Using plants as an exploration tool for gold.

F.D. Busche

The purpose of this paper is to discuss the biogeochemical sampling techniques used by Shell Mining Company. The problems associated with sampling for gold in secondary environments of exotic overburden are well known. Use of a sample medium able to see through transported material would be advantageous. Both soil and humus sampling results might be compromised by the well known "Nugget Effect". In addition, both soil and humus sampling are somewhat affected by small amounts of transported cover over the target of interest.

Plants have certain characteristics that make them perfect candidates for use as a gold geochemical sampling medium. Because roots take up nutrients from the underburden, a plant tends to integrate the substrate over the extent of its root system. This integration removes the problem of the "Nugget" that is encountered when using other sampling mediums. In addition, the plant roots are able to obtain samples of mineralized bedrock that may lie underneath an exotic overburden. Finally, since plants have root systems that extend deeply into the colluvium or soil, anomalous values should not migrate far from their source as a result of downslope movement in areas of high relief. These attributes make plants especially appropriate for use as a medium for sampling over transported soil or on steep slopes.

The areas identified on the two properties discussed below probably could not have been delineated by either soil or humus sampling. All analyses were carried out by the use of Instrumental Neutron Activation Analysis. This analytical technique enables one to obtain analysis for gold in plants to a detection limit of 0.2 parts per billion. As an added bonus, 30 additional elements are determined on each sample simultaneously.

The Standard Hill Property is located approximately 100 kilometers north of Los Angeles, California near the town of Mojave, California. The purpose of the biogeochemical sampling program at Standard Hill was to extend known gold mineralization under an exotic colluvial overburden. Sagebrush and creosote bush leaves and twigs were selected for the orientation survey over areas of known mineralization. Because of its wider distribution and presumed greater root system, the creosote bush was selected as the plant to use for the overall survey. Leaves of the creosote were used as the plant part for the survey because of the higher peak to background ratio obtained using them during the orientation survey. Sample points were taken on the initial survey at 30 meter spacings. A follow-up survey was completed over part of the area on a 15 meter grid. We were able to extend the known mineralized areas under the overburden to depths approaching 30 meters.

The second area in California upon which a biogeochemical survey was completed is called the Zenda area. The Zenda area is located approximately 50 kilometers east of Bakersfield, California. The purpose of the survey at Zenda was to locate any areas of interest that may have been missed in an earlier rock chip sampling program. A large percentage of Zenda is covered by residual soil but the steepness of the slopes make the use of soil sampling less than desirable. As a result of orientation work completed in the area, the leaves of the scrub oak and juniper trees were selected as the sampling medium. Plant sampling was carried out on a 70 meter grid. Anomalous areas of gold and arsenic were identified as a result of histogram and cumulative frequency probability plot analysis of the plant data. Comparison of the areas found anomalous by rock chip sampling with those determined by plant sampling produced only one new area that had not been identified by rock chip sampling. The new area showed anomalous values in both scrub oak and juniper leaves for gold and arsenic. Unfortunately, the area identified by the plants is located under the path of an aerial tram that had been used some 70 years earliers as a method of transferring ore from the mines to the mill. No anomalous gold or arsenic values have been detected in the rocks that outcrop nearby. The plants have located an area contaminated by spillage of gold ore that had been carried by the aerial tram.

In summary, as has been illustrated in the cases discussed above, plant sampling is an inexpensive and accurante means of delineating gold targets. Plant sampling is especially preferential to use over soil sampling when the area to be surveyed is either covered by shallow alluvium and/or is located in an area of high relief.

Samples were grouped by the transect's five different lithologies : Tertiary quartz latite porphyry, and Cretaceous Pierre shale, Niobrara limestone, Benton shale, and Dakota quartzite. Initially, only metal concentrations in needles were examined to assess lithologic dependence.

Average Au concentrations in needles varied between lithologies. November, and March sampling periods had lower average Au concentrations, but increased in both years during May and July, except Pierre shale which peaked in September both years. Year 02 concentrations were lower than Year 01 concentrations over all lithologies.

The only variable difference between these years was climate. Precipitation and temperature data were used to calculate soil water balances in two week intervals. The soil water balances indicated that Year 02 moisture deficits were significantly less than Year O1 soil water deficits. With more soil water available, the forest vegetation would have to rely less on deep water or smaller interstitial waters for evapotranspirational needs. Data from La companion study, show that solute concentrations decrease with increased pore volumes, thus lower soil solution metal concentrations would be expected for the wetter periods.

Average Cu and Zn concentrations in needles over the entire study period showed no significant differences in bioavailability by lithology. Again, Mo and Pb concentrations were low in biogeochemical samples and could not be discriminated by lithology.

Availability and uptake of some metals by plants varies over time and appears to exhibit a lithologic dependence. Soil geochemical and biochemical processes may be responsible for this behavior and are being addressed to further improve the utility of biogeochemistry.

Platinum-group metals in common plants of northern forests : developments in analytical methods and the application of biogeochemistry to exploration strategies.

C.E. Dunn
G.E.M. Hall

The few published studies of platinum-group metals (PGM) in trees and shrubs have demonstrated the ability of some plants to concentrage up to several thousand ppb PGM (in ash). Clearly, this recognition opens the possibility of applying biogeochemical methods to assist in the discovery of PGM mineralization. In Precambrian Shield areas of the northern hemisphere. the exploration geologist commonly faces problems of extensive forest and drift cover concealing bedrock : analysis of these plants may provide information on the composition of the substrate. Before biogeochemistry can be effectively applied to PGM exploration, it is necessary to establish concentration patterns of these elements within and among plants, and to improve the sensitivity of analytical methods.

Investigation of plants growing near a platiniferous nickel sulphide deposit in Saskatchewan has found that ashed twigs and trunkwood of black spruce (Picea mariana) and jack pine (Pinus banksiana) have a propensity to concentrate PGM. Values in spruce twig ash of up to 880 ppb Pt, 1300 ppb Pd and 24 ppb Ir are recorded, with 6-10 ppb Rh in other plant organs. Concentrations in conifer needles are an order of magnitude lower. However, some deciduous species (e.g., alder (Alnus crispa), and labrador tea (Ledum groenlandicum)) appear to have less differentiation of PGM between leaf and twig, with generally lower values than in the conifers.

Concentrations of the levels indicated above are exceptional, and can only be expected in close proximity to high-grade PGM mineralization. Background levels are typically below usual detection limites of 10 ppb Pt, 2 ppb Pd and 2 ppb Ir. However, near low-grade mineralization (e.g., 100 ppb Pt in a diabase dyke), platinum is significantly higher than background in both spruce twig and bark (30 ppb Pt in ash). This discovery lends credence to the contention that biogeochemical methods may be of use in outlining zones of concealed PGM mineralization.

A major problem to date has been the large sample of vegetation required to determine PGM in the few ppb range. Ideally, 50 g of ash is required for an effective fire-assay extraction of PGM in a NiS bead prior to neutron activation analysis, and the technique is expensive. About 1500 g of dried leaf, 2500 g of dried twig, and 10 kg of dried conifer trunkwood is required to produce 50 g of ash. Such large initial samples are quite impractical for the exploration geologist. Valuable data (with detection limits of 10 ppb Pt and 2 ppb Pd) can be obtained on ash samples of 10 g, but there remains a pressing need to obtain these detection limits (or better) on 1-2 g of ash. This problem is being addressed at the laboratories of the Geological Survey of Canada.

Recent work has established reliable detection levels of 5 ppb for platinum, palladium and rhodium on only 2 g ash, and plans are in hand to improve this determination limit by an order of magnitude.

The analytical method currently employed is to ash the vegetation at 470°C and dissolve 2 g in HF and aqua regia. Tellurium co-precipitation of several precious metals is undertaken to separate and concentrate PGM from the matrix elements. Stannous chloride is added as a reductant. Analysis is performed by graphite furnace - atomic absorption spectrometry, calibrated with synthetic solutions taken through the same procedure.

In the near future measurement will be made by inductively-coupled plasma mass spectrometry (ICP-MS), with sample introduction by electrothermal vaporization to further reduce detectionlimits. Samples will be spiked with appropriate PGM isotopes, thereby eliminating the effect of interferences in the ICP-MS analysis and permitting estimation of any analyte losses (e.g., to filter paper) during the sample preparation stages.

Once the analytical methodology is perfected and detection levels of 1 - 2 ppb Pt and Pd can be obtained on 1 g samples of ash, biogeochemical methods may be applied routinely in appropriate geological terrains to assist in delineating platiniferous zones. At the present time. the significant recent advance in reducing to 2 g the amount of ash required for analysis has made biogeochemistry a practical adjunct to an exploration program. The widespread distribution of black spruce throughout vast areas of Precambrian Sheil points to this species as one of the most useful for PGM exploration.

Geobotanical and biogeochemical exploration for gold in the Sattasuaara volcanic complex finnish Lapland.

E. Pulkkinen
M.L. Raisanen
L. Ukonmaanaho

The Sattasvaara volcanic complex is located in Finnish Lapland, 120 km North of the Artic Circle. The rocks of the study area are mainly basaltic komatiites in composition and belong to the early Proterozoic Central Lapland Greenstone Belt.

The Sattasvaara area lies within the accumulation area of most of the Pleistocene glaciations and, consequently, the glacial erosion has been weak. The drift is composed mainly of till but sand and gravel deposits occur in the areas of thick drift (10-40 m). The glacial transport of till is relatively short.

In the study area the annual mean temperatures is 0°C and precipitation 400 mm. The duration of the winter is from 175 to 220 days. The mean thickness of the snow cover is 70 cm. The effective growing season for most of the plants (≥10° C) is 81 days on the average.

The study targets, gold mineralizations, occur within the volcanic complex. Gold is associated with carbonatized and albitized rocks and hydrothermally altered talc-chlorite-mica-carbonate-barite-quartz rock.

It was found, for instance, that zones of dense growing juniper (Juniperus communis), and occurrence of mezereon shrubs (Daphne mezereum), roebuck berry (Rubus saxatilis) and lesser club moss (Selaginella selaginoides) indicate the carbonate and mica altered rocks. In the Pahtavaara target, the top horizon of the podsolic soil has been enriched in nutrients (fertilized) driven from underlying weathered rocks. The amount of exchangeable Ca and Mg cations in the soil is two to three times higher in the fertile zone than in the areas of less dense vegetation with fewer species. Furthermore, the amount of bioavailable Ca and/or Mg depends on the grade of weathering of the underlying altered rock and on the thickness of till cover. The severe climate emphasizes the effect of the fertility of the soil on the vegetation.

Gold contents of some evergreen plants associated with two Au showings were analyzed : (1) Pahtavaara, where Au content in soil is from 0.01 to 8 ppm and (2) in Rajala from 0.01 to 3.6 ppm. In each target twigs of juniper and the parts of other plants growing above the ground were sampled from areas of an are in size. The samples were ashed and analyzed for Au from aqua regia dissolution by AAS graphite furnage atomization. The preliminary results are given in table 1.

Table 1 : Au content (ppb) in the ashes of some evergreen plants growing on Pahtavaara and Rajala Au showings

Plant species	Pahtavaara	Rajala
Crowberry (Empetrum nigrum)	> 1	120
Juniper (Juniperus communis)	73	17
Mosses (Hylocomium spendes)	8	3
(Pleurizium schreberi)	45	6

In summary, the preliminary results indicate that geobotanics can be used to locate carbonate altered areas in the Sattasvaara volcanic complex and, furthermore, possible Au content is reflected in plants. The study is still in progress to find out which species of the plants are the most pratical in exploration for Au.

Temporal variation and lithologic dependence of metal concentrations in biogeochemical samples.

J.D. Stednick
W.C. Riese

Lodgepole pine (Pinus Contorta) was determined to be useful for biogeochemical prospecting. Metal concentrations in biogeochemical samples varied within and between years and suggested that availability and uptake of some metals by plants may be lithology dependent.

The study area was near the Royal Tiger Mine in the Breckenridge Mining District of Colorado, U.S.A. The mine workings were located within a fault-bounded breccia complex which is well mineralized with Cu, Pb, ZN, Au, Ag, and Bi. Both mine workings and exploration drilling provided underground geologic control.

Samples of lodgepole pine were collected every two months for nine sampling periods, May 1983 to September 1984. Needle, twig, and wood samples were taken at sixty-five points at 15-meter intervals along a 1 km transect line and analyzed for Cu. Zn, Pb, Mo, Au, and Ag. Needle and twig samples were ashed before acid digestion and analyzed by ICAP and AA. Wood samples were analyzed by neutron activation. Soil samples were taken from the B horizon, acid digested and analyzed by AA for total metals.

Gold concentrations in needle and twig samples identified anomaly/background contrasts, although large temporal and spatial variations occurred. Gold concentrations in needles paralleled those in twigs at roughly half the concentration.

The highest Au concentrations occurred in September 1983 (Year 01) when a large anomalous zone was defined. The anomaly was later determined to be a massive metal-bearing skarn with a high Au content. This anomaly demonstrated the ability of the trees to absorb significant quantities of available Au and more importantly locate a deep Au source not reflected in soil samples. The anomaly/background contrasts that were observed in Year 01 were not observed in Year 02 sampling. This temporal variation in plant available Au suggests that the optimum biogeochemical sampling window is certainly shorter than the 2 month sampling period, and may be as short as 1-2 weeks. Gold concentrations in wood samples were low and generally occurred as scatterred single point anomalies ; wood therefore was judged to be an unsuitable sampling organ for exploration purposes.

Mineralized areas were consistently identified by Cu concentrations in needle twig samples. Copper concentrations in needles consistently paralleled those in twig samples at roughly half the concentration. The relatively stable Cu concentrations may be due to the role of Cu as an essential element in plant nutrition, or alternatively, may reflect minimal changes in the bioavailability of Cu.

Zinc concentrations in needles and twigs consistently reflected mineralization with little temporal or spatial variation. Like Cu, Zn concentrations were relatively stable in needle and twig samples over time.

Twigs contained higher Pb concentrations than needles, but concentrations were erratic both along the transect and over time. Whether these results are due to low Pb concentrations in the soil or a plant uptake exclusion mechanism is not known, but Pb was unsuitable for biogeochemical sampling in this area.

Molybdenum concentrations were generally low in all samples, often below detection limits. Low Mo concentrations in both soil and biogeochemical samples made Mo unsuitable for exploration purposes in this area.

Very low Ag concentrations in soil and biogeochemical samples also precluded their utility for exploration purposes. Most metal concentrations in wood samples were generally low, often near detection limits and did not reflect soil metal concentrations or mineralization. As in the case of Au, wood samples were unsuitable for exploration purposes.

Biogeochemical sampling was proven to be useful for delineating mineralization from year to year. However, temporal variations of metal concentrations in plants within and between years had to be recognized, as well as apparent lithologic influences on these variations. In order to assess the role lithology might play in regulating metal bioavailability to plants, biogeochemical sampling points were discriminated by lithology.

Thème 6 : PROSPECTION SOUS RECOUVREMENT ALLOCHTONE

Topic 6 : EXPLORATION IN TRANSPORTED OVERBURDEN

Un résultat remarquable de la prospection géochimique sous recouvrement de limons : la découverte du gisement d'antimoine des Brouzils.

A. Allon
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R. Vasquez-Lopez

Situé à une quarantaine de kilomètres S.S.E. de Nantes, le gisement d'antimoine des Brouzils appartient au district antimonifère vendéen, qui a produit au 19ème et début du 20ème siècle, 18 000 t d'antimoine provenant du filon de Rochetrejoux (16 500 t Sb extraites) et d'une dizaine d'indices voisins. Par contre de nombreux indices et en particulier le filon des Brouzils, localisés dans un environnement pénéplané mal drainé et masqué par une épaisse couverture de limons, ont totalement échappé aux investigations des prospecteurs du début du siècle. Leur découverte est à mettre à l'actif de la prospection géochimique.

Les formations du Paléozoïque inférieur à grauwackes, schistes gris ou verts et interstratifications de matériel volcanique, constituent l'encaissant des filons. Elles sont intensément plissées (synclinorium de Chantonnay et anticlinal des Essarts) et affectées par la tectonique tangentielle sud-armoricaine, de direction WNW-ESE. Les systèmes de fractures conjuguées contrôlent le plus souvent les veines minéralisées les plus significatives.

L'abondance des limons de plateaux, argiles quaternaires proparte allochtones, qui couvrent des surfaces considérables sur une épaisseur de un à plusieurs mètres, est une particularité du domaine vendéen qui gène considérablement les observations et les prospections géochimiques classiques.

Une couverture géochimique stratégique multiélémentaire a couvert l'ensemble des zones favorables de la région, à la densité de 3,3 éch./km^2 prélevés dans les thalwegs et répartis de façon à contrôler les migrations éluviales et alluviales à la base des interfluves. Elle a fourni de nombreuses anomalies d'antimoine (20 à 49 ppm), arsenic, plomb, parfois très discrètes mais significatives.

Une étude méthodologique le long de coupes pédologiques dans les formations de recouvrement a montré leur stérilité géochimique ; elle a de même mis en évidence la dilution des prélèvements de stream-sediments par les apports de limons.

L'enracinement des anomalies a donc été recherché par des prélèvements aux interfluves du bed-rock altéré à la maille de 400 x 20 m resserrés à 200 x 20 m et localement 50 x 10 m. Cette approche géochimique a été complétée par des prospections marteaux et par des levers électromagnétiques (V.L.F.).

Ces travaux ont conduit à délimiter aux Brouzils une enveloppe anomale N.S. de 3 km de long, large de 300 m en moyenne avec des valeurs anomales en Sb atteignant 800 ppm.

La reconnaissance des structures favorables par tranchées. puis dans le plan vertical par forages percutants et sondages carottés hydrofore, a permis une excellente focalisation des anomalies géochimiques sur les têtes des filons. Ces travaux ont mis en évidence une dizaine d'indices nouveaux, dont le champ filonien des Brouzils. Celui-ci est constitué par un groupement de filons NS et NE-SW de 0,20 m à 2 m de puissance, dont le potentiel minier actuel est estimé à 5 000 t d'antimoine métal réparti sur 7 à 8 colonnes riches. dans un minerai titrant 5 à 7 % Sb.

Parallèlement à ces travaux, la recherche de nouvelles structures a été poursuivie par resserrements de la maille d'échantillonnage à 8-9 éch./km^2 sur des aires sélectionnées d'après les données linéamentaires. Les prélèvements de stream sediments dans les interfluves permettent en effet de s'affranchir pro-parte des fortes dilutions provoquées par des matériaux stériles des limons de couverture. La bonne concordance des premiers résultats laisse espérer de nouvelles découvertes.

Ajustment of soil gas analysis for geochemical prospecting.

P. Degranges
J.Cl. Baubron
D. Defoix
T.K. Ball
R.D. Nicholson

Gas-geochemical techniques have been used over different types of mineral deposits in France and United Kingdom. Volatile elements and compounds in gases derived from the soil were analysed in order (1) to optimize methodology, especially in-situ analysis, (2) to see which volatile components might be indicative of each type of orebody, (3) to examine instances in which gaseous methods have been ineffective or successful. Comparative work between French and British teams was made on these different deposits.

Soil-gas data were obtained for oxygen, carbon dioxide, helium, radon, argon, sulphur compounds and mercury. New techniques involving gas chromatography and mass spectrometry have been adapted for field analysis.

The areal distribution of soil gases and volatile components has been studied over a zinc-lead-silver deposit in carbonate environment (St-Salvy, France), and a tungsten-bearing stockwork in granite (Hemerdon, United Kingdom).

Relationship between the nature of overburden and environment, the organic carbon content, some meteorological factors and soil-gas content have been studied for determining gas anomalies which are related to concealed orebodies. Higher than average concentrations of carbon dioxide, argon, helium and carbonyl sulfide are found over the orebody at St Salvy and Hemerdon. Helium is a good fault indicator in every case.

Results of the investigation reported give indications about powerful or limiting conditions for the successful application of gas geochemical methods. Nevertheless, more fundamental work about diffusion and concentration process of volatiles emanating from sulphide mineralisation seems important because of some ambiguities that affect the interpretation of the data.

Contribution of organic geochemistry to the regional exploration of sulphide mineralization.

B. Gauthier
J.R. Disnar

The sensivity of organic materials to physicochemical and/or biological events that may affect its environment makes it a remarkable marker of the various processes that may occur in geological systems. The possibilities offered by this property have been illustrated previously in the case of the Zn-Pb Trèves deposit (Gard, France) where organic petrographical and geochemical studies have made it possible to propose a new genetic model for this mineralization. This involves hydrothermal fluids responsible for the dolomitization of the host rocks and for the oredeposition at the favor of a synchronous development of sulfate-reducing microorganisms (Gauthier et al., 1985a and b : Gauthier, 1984 ; Disnar et al., 1987).

The present study deals with similar analytical data obtained from borehole and surface samples from the same region : the eastern border of the Causses basin (from Florac in the north, to Les Malines in the south), using, two different but complementary approaches. The first one consists in a simple recognition of the signatures left by hydrothermal or epigenetic processes on the organic constituents contained in the formation that they have affected. The methods used for this purpose where those routinely applied by organic geochemists : Rock-Eval pyrolysis ; analysis of the bitumens by chromatographic techniques and possibility also by mass-spectrometry. The second approach is directed since it uses the capacity that volatile hydrocarbons have of migrating through the rocks, and thus of transporting to the surface information about events that occurred at depth.

The results obtained by these two approaches are in agreement and indicate that the thermal and biochemical processes previously demonstrated in the Trèves area were in fact of regional extent. Their intensity progressively increases from north to south across the basin, parallel with the know regional metallogenic potential which culminates in the area of Les Malines mine.

The results and the low cost of some of the applied methods indicate the interest of studies of organic material for mineral exploration, at the regional and details scale.

References :

Gauthier B. (1984) - Thèse Université d'Orléans, 210 p. ;

Gauthier B., Disnar J.R., Macquar J.C. et Trichet J., (1985a) - C.R. Acad. Sc. Paris, 301, Sér.II, pp. 33-38 :

Gauthier B., Disnar J.R., Macquar J.C. et Trichet J. (1985b) - C.R. Acad. Sc., Paris, 300, Sér. II, pp. 413-416 ;

Disnar J.R., Gauthier B., Chabin A. et Trichet J. (1986) - Org. Geochem. 10, pp. 1005-1013 ;

Découverte d'extensions du gisement polymétallique de Thalanga sous couverture puissante, par application de la géochimie tridimensionnelle Pb, Zn, Cu, Ag (Queensland - Australie).

Cl. Granier
J. Hartley
J.C. Michaud
G. Troly

En 1974, la Société Minière et Métallurgique de Penarroya avait retenu parmi ses projets d'exploration, la recherche d'amas sulfurés polymétalliques dans les formations appartenant au géosynclinal tasman. En se basant sur l'environnement géologique classique de ce modèle conceptuel de gisement, plusieurs régions ont été sélectionnées à partir d'études bibliographiques et d'itinéraires géologiques.

Dans les zones à dominante volcano-sédimentaire, une recherche systématique des chapeaux de fer a été entreprise. En 1975, un permis a été posé couvrant le chapeau de fer anomal situé à Thalanga, 60 km à l'Ouest de Charters Towers au Queensland.

Le premier sondage fait en octobre 1975 a recoupé plus de dix mètres de sulfures massifs à haute teneur.

Depuis, les travaux se sont développés tant sur le gisement que dans la région. Une province de 70 km d'extension Ouest-Est a été mise en évidence par la géologie et la géochimie, car les affleurements sont très peu nombreux. Les indices et les anomalies se situent dans un horizon bien défini des Mount Windsor Volcanics d'âge cambro-ordovicien. Le contrôle par sondages d'une anomalie de la prospection géochimique régionale amena en 1985 la découverte d'une lentile riche, Waterloo, à 35 km à l'Est de Thalanga.

En 1976, Penarroya a constitué une Joint Venture avec des partenaires australiens dans laquelle les parts sont actuellement :

Penarroya (Australia) Pty Ltd :	50 %
BHP	39,24 %
E.Z.	10,76 %

Sur le gisement de Thalanga, 40 000 m de sondages ont été effectués ainsi que des travaux miniers de reconnaissance. A ce jour, 8 millions de tonnes ont été mises en évidence, aux teneurs d'entrée en laverie suivantes :

2,2 % Cu, 2,7 % Pb, 8,7 % Zn, 71 g/t Ag, 0,5 g/t Au

En 1980, la recherche vers l'Est d'extensions de la partie déjà reconnue a débuté par une prospection géochimique en sondages destructifs au travers d'une épaisse formation de conglomérats tertiaires (Campaspe Beds).

Quelques profils en sol indiquaient la possibilité d'une minéralisation sous la couverture dans cette direction.

A cette époque, la connaissance des faciès montrait que la minéralisation se situait au contact de formations rhyolitique au mur et dacitique au toit.

Le recouvrement détritique des Campaspe Beds dont la puissance atteint 80 m oblige, pour trouver les extensions du gisement, à utiliser une méthode de géochimie tridimensionnelle par profils de sondages destructifs analysés par passe complète de trois mètres.

Des projets de sondages ont été implantés suivant un espacement régulier perpendiculairement à la direction structurale générale. La logique d'implantation des sondages sur chaque profil a permis de repérer la position du contact au moindre coût.

L'analyse multi-élémentaire des échantillons a déterminé les profils sur lesquels une dispersion géochimique existait.

Dans ce cas, des sondages carottés étaient implantés pour recouper le contact.

Cette prospection a permis la découverte de minéralisations économiques qui ont augmenté sensiblement le tonnage.

An attempt for selectively using the chemical dispersion of metals to search for hidden deposits.

L. Laville-Timsit
E. Wilhelm

In geochemical exploration, the overall signal detected by analysis of stream-sediment or soil samples integrates several components mostly controlled by lithology and soil development in the vicinity of any individual sampling site. These main factors result in important fluctuations of the geochemical background, sometimes making it very difficult to identify "true" anomalies issued from mineralization.

If the sought mineralization crops out, the resulting geochemical anomalies are usually well contrasted because of their mostly detrital origin. The formation of such anomalies may be explained by the mechanical dispersion of secondary stable metal-rich minerals such as oxides, silicates, phosphates or, to a lesser extent, of primary sulphides.

Whatever be the importance of the detrital component of a given geochemical anomaly, the participation of chemical processes cannot be neglected, especially for non-outcropping mineralization. Indeed, in such situations, secondary geochemical dispersion can only be achieved through a sequence involving leaching, transport into solution and final immobilization at some distance, by processes such as precipitation or adsorption on some specific mineral or organic phases.

Identifying and separating the chemical component of a raw concentration for a given element in a geochemical sample is therefore essential but always difficult because it represents only a very small proportion of the overall value. Our approach mostly consists in (1) separating different grain size fractions of stream-sediment samples collected in background areas and near buried sulphide mineralization and (2) analyzing these fractions using both total and selective chemical attacks. Simultaneously, the chemical dispersion around the same mineralization was studied by analysis of surface or ground water samples.

As for "solid" (stream sediment) samples, the main results obtained can be summarized as follows :

- for background samples, the contents of key elements such as Zn are low and evenly distributed in the different size fractions, with however enrichment in the ultra-fine (5 um) fraction. This enrichment was proved to be mainly related to a different mineralogical composition, with a higher proportion of phyllosilicates, relatively enriched in several elements, including Zn ;

- for samples collected near mineralization, the metal contents are still very low in the total samples, and also in any individual coarse, medium and fine fraction. On the contrary, in the ultra-fine fraction, highly anomalous Zn contents were obtained (800 to 2000 ppm), corresponding to an anomaly/background ratio averaging 5. Furthermore, such high contents and contrasts were shown not to be related with silicates, as they are readily extractible by weak chemical reagents. Very likely Zn is present in the ultra-fine fraction, closely associated with organic matter, sulphides, cristalline or amorphous Fe oxi-hydroxides and, to a lesser extent, Mn oxides.

The anomalies thus obtained may be considered as resulting from hydromorphic dispersion processes around mineralization, as confirmed by the very similar results obtained by hydrogeochemistry. Indeed, there is a fair coincidence between the distribution of anomalous Zn values in water samples and in the ultra-fine fraction of stream sediment.

In the specific conditions of our work, it was possible to selectively measure, in stream-sediments samples, the Zn geochemical anomaly strictly related to chemical dispersion processes. However, an attempt to use this technique (separation and analysis of the ultra-fine fraction) at a routine scale was unsuccessful, for time and cost reasons.

Recognition of hydrothermal alteration patterns in soils and bedrock using anion geochemistry.

P. Lechler

Structurally-controlled hydrothermal alteration is commonly characterized by quartz-sulfide or quartz-alunite(-sulfide) veins or planar replacement zones flanked by argillic or advanced-argillic alteration. These systems exhibit high sulfate/low chloride in the quartz-sulfide(-alunite) zone and high chloride/low sulfate in the argillic zone. The high sulfate/low chloride zones reflect the oxidation of sulfides to soluble sulfates and/or the partial solubility of alunite-sulfate. The high chloride/low sulfate zones result from the probable substitution of chloride (from chloride-rich hydrothermal solutions) for hydroxyl ion in the alteration minerals kaolinite, sericite, etc., and the paucity of sulfides in these zones. Data from the Comstock silver-gold district, Nevada and a granite-hosted uranium deposit at Copper Mountain, Wyoming are presented.

Argillically altered rocks also exhibit high nitrate abundances, perhaps an oxidation product of hydrothermally introduced ammonia. Equations showing the probable oxidation path, and appropriate free energy values indicating favorability are presented.

These consistent patterns of adjacent high sulfate/high chloride zones are clearly reflected in anion abundances in overlying soils in semi-arid environments, but appear poorly-represented in areas of higher rainfall, although additional studies will be required to confirm the latter. Discriminating between high sulfate-chloride abundances related to either simple alkali soils or hydrothermal alteration is discussed. Specific examples of recognizeable hydrothermal anion patterns and their use in mapping structurally-controlled alteration zones are presented.

The often-observed close association between oxidized iron sulfides and reduced ore species such as native gold and U308 suggests a direct genetic link. The sulfate liberated by such redox reactions can produce significant bedrock haloes proximal to metal mineralization as is described for uranium at Copper Mountain, Wyoming. Thus, while the target elements are concentrated at discrete redox centers, the liberated sulfate undergoes dispersion into the surrounding host rock producing a broadly-detectable halo. The pronounced systematic variations in resultant sulfate-chloride ratio can be a valuable tool for guiding exploratory drilling. An example from Copper Mountain is presented.

Sample preparation consisted of sieving soils to -80 mesh and pulverizing rock samples to -100 mesh. Four hundred milligrams of sample powder was leached with 10 ml deionized water in sealed borosilicate test tubes for 1hr at 100 degrees C. Leachates were analyzed with a Dionex 2000i/SP ion chromatograph.

One sigma relative precision of measurement is +/- 2.33 % for chloride and +/- 2.15 % for sulfate. Soluble chloride abundances range from 3 to 761 ppm in soils and from 4 to 660 ppm in bedrock ; soluble sulfate ranges from 5 to 12310 ppm in soils and from 36 to 8060 ppm in bedrock.

Effects of supergene contamination of bedrock alteration samples were evaluated by washing coarsely-ground sample material with cold deionized water, drying, pulverizing, and then leaching by standard hot water procedures ; significant results will be discussed.

On the relationship between primary and secondary geochemical fields in deep-seated deposits.

A.D. Lobanova

Mineral deposits are defined as natural element assemblages. Therefore, in spite of genetic type, structure and mineral composition, the formation of deposits (concentration of elements) is followed by their immediate decomposition (dissemination of elements). The main reason for this appears to be a process of molecular diffusion occurring at the boundary between solid (a mineral fragment) and liquid (film moisture surrounding the fragment) phases.

A system moves toward equilibria according to Fick's first law

$$dn_i = -D_i S \frac{dc_i}{dx} dt$$

A a result, besides well-known primary syngenetic halos characterized by complex structure and composition, there are the diffusive fields of deep-seated deposits. Ore elements which form these fields are predominantly located in film moisture and are all in the ionic form.

The primary diffusive geochemical field should involve all elements composing mineral assemblages in a particular deposit. According to equation, field intensity is proportional to the difference in abundance of elements between mineral fragments and a liquid film (dc_i), to the degree of ore substance dispersion (s) and to age of the deposit ; all other conditions being equal.

The information about the composition of deep-seated deposits is transferred to the Earth's surface by film moisture involving several intensive parameters namely the temperature gradient of heat flux, potential gradient of electric flux, pressure gradient of mass flux and chemical potential gradient of the element flux in a solution.

The fact about film transport during thermoosmosis and electroosmosis is supported by experimental data. Our field studies indicate a highly important role of molecular diffusion induced by the concentration gradient.

Because of the universal character of diffusion processes all elements occurring in a primary geochemical field and characterized by different concentrations in orebodies and overlying rocks should aso be present in the diffusive mass flux.

Deep-seated deposits are related to the Earth's surface by the always travelling diffusive ion flux. By approaching the Earth's surface the indicator elements bring about the formation of natural salt efflorescences over deposits during unloading film waters, take part in aqueous migration, are absorbed by soil and plants and turn out to be fixed on adsorption surfaces by forming insoluble compounds. i.e. these elements bring about the formation of superimposed diffusive haloes.

In arid and frozen regions where aqueous diffusion is limited or even absent such haloes are the direct surface projections of orebodies. In humid regions where diffusion is partially suppressed by filtration, diffusive haloes are weak and sometimes are displaced from orebodies to overlying rocks.

Element compositions of secondary geochemical fields measured on the Earth's surface are usually formed not only by deposits but in a large extent by enclosing and overlying rocks. Therefore, the interpretation of secondary geochemical anomalies turns out to be a difficult task.

A method which can be used to divide the experimental data into individual element assemblages related to certain areas, appears to be highly promising. The paragenetic analysis helps the problem to be solved.

It is known that the process of element concentration occurs not in a random fashion but is dependent on physical and chemical properties of the elements and on the formative processes in the deposit. Early in the twentieth century V.I. Vernadsky proposed the idea of element paragenesis as joint occurrence of element groups which are characterized by similar physical and chemical properties and reveal qualitative and quantitative relationships.

Later developments of the doctrine of parageneses as natural geochemical element assemblages have helped to propose geochemical criteria of mineralization in certain regions and igneous masses. These criteria are widely used in modern search for mineral deposits. Nevertheless, it should be noted that the idea of coexisting elements is based on empirical data which not always fit in well with the conception of paregenesis.

The formation of mineral deposits is a complex process ; for this reason there is no general agreement about the origin of orebodies. In igneous and hydrothermal deposits the composition of ores is affected not only by magma chambers and ore-bearing solutions but also by xenogenic materials and ore components in ore-enclosing rocks ; these components are subject to migration toward heated zones during thermoosmosis. Thus co-existence of elements cannot be considered as a paragenetic criterion.

The conception of paragenetic assemblages is that of a group of elements coexisting in the deposits, characterized by identical geological history during ore formation processes and as a result, by identical variations in their concentrations. Such variations provide the unfailing criterion that may be used to locate natural parageneses.

The variations in the element concentrations can be estimated by multi-statictical technique. If the information about the investigated object is complete, the method of main components provides good results because this method offers the best correspondence to the idea of paragenetic analysis.

A localization of paragenetic assemblages is based on the analysis of correlation matrices by the method of main components. This localization permits to avoid subjectivism in prospecting for indicator elements (parageneses) in both primary and secondary geochemical fields.

Study of secondary geochemical fields from a position of paragenetic analysis (biogeochemical data) reveals a correlation between element parageneses in ores (rocks) and secondary diffusive haloes in all types of deposits and overlying rocks. Geochemical factors affect the variations in the composition and structure of parageneses ; these variations can be restored allowing for chemical compositions of the rocks and aqueous element migration in a particular region.

The correlation between element parageneses in primary and secondary geochemical fields was discovered in arid, humid and frozen regions on examples of copper-molybdenum 1, copper-nickel 2, and copper 3 mineralizations. The maximum thickness of overlying rocks was 200 m in a cryolithozone.

Utilisation du facteur d'adsorption en prospection géochimique : Exemple de l'Uranium dans les sédiments de ruisseau.

J.C. Samama
J.J. Royer
C. N'Ganzi

Dans les réseaux hydrographiques, les éléments métalliques issus des gisements, occurrences et roches banales, sont véhiculés sous des formes très variées allant du grain minéral (exemple cassitérite) à la solution vraie en passant par les colloïdes et les formes de fixation sur des phases minérales ou organiques. Deux méthodes distinctes de prospection découlent de cette répartition : l'hydrogéochimie et la prospection en sédiments de ruisseau.

En fait, classer les formes de transport est techniquement difficile et souvent arbitraire puisque l'expérience montre que le stock total transporté se répartit par tranches granulométriques et que les données concernant le transport en solution reposent sur un filtrage à 0,2 µ. Mais le devenir de ce stock métal est tout aussi complexe puisque suivant le cas, le dépôt mécanique, la précipitation, l'adsorption, la floculation et la fixation organique contrôlent la charge véhiculée par l'eau et le sédiment déposé. Mode de transport et mode de dépôt vont dépendre du système climat-hydrographie, mais aussi de la forme sous laquelle l'élément chimique concerné est présent dans son site géologique initial du bassin amont.

La connaissance des mécanismes de transport et de fixation peut, bien entendu, améliorer les techniques et les interprétations de prospections géochimiques. La présente note a pour object de montrer comment la connaissance des phénomènes d'adsorption d'un élément, l'uranium, peut améliorer l'interprétation (sélection) d'anomalies.

Transport et fixation de l'uranium

Comme cela apparaîtra au paragraphe suivant, le transport de l'uranium en milieu intertropical humide semble principalement régi par les phénomènes d'adsorption sur les hydroxydes de fer.

L'indice de transport en solution de l'uranium, c'est-à-dire le rapport du stock "dissous" (c'est-à-dire passant dans les filtres micropores à 0,2 µ) stock voyageant ou comme matière en suspension est de 0,03 pour des environnements ordinaires. Cette assez faible valeur de l'indice pour un élément, réputé soluble aux teneurs habituelles sous forme d'uranyle carbonates, s'explique précisément par l'aptitude à l'adsorption sur des phases minérales et organiques.

Le rôle des hydroxydes de fer peut être mis en évidence aussi bien à partir d'échantillons naturels (étude analytique de phases ferrifères en milieu riche en uranium) que d'expérimentation (isotherme d'adsorption) sur des phases ferrifères naturelles ou synthétiques. De ces études, il apparaît :

- que l'adsorption est un processus de fixation très efficace ; le coefficient d'enrichissement géochimique (rapport de la teneur solide celle liquide à l'équilibre) est très élevé : 1.10^6 pour un hydroxyde de fer synthétique frais, $2{,}5.10^4$ pour une geothite naturelle, 3.10^3 pour une hématite et $7.8.10^3$ pour une kaolinite ;

- que la cinétique de fixation est élevée, expérimentalement, les équilibres sont atteints en moins d'une heure ;

- que les systèmes sont réversibles (désorption) ;

- que l'intensité du processus est influencé par le pH du milieu (par exemple, sur le même matériel, coefficient d'enrichissement variant de $2.5.10^4$ à pH 6.5 à $6{,}6.10^3$ à pH 4,5 pour une goethite naturelle).

L'importance de ces données va apparaître à la lumière de l'exemple type choisi.

Exemple de distribution de l'uranium dans les sédiments de rivière du Gabon

Des échantillons ont été prélevés en lit vif dans deux réseaux hydrographiques drainant des zones minéralisées non exploitées du Francevillien du Gabon. Sur 81 échantillons analysés en SiO_2, Al_2O_3, Fe_2O_3, FeO, TiO_2, MgO, MnO, K_2O, Na_2O, P_2O_5, PF, B, Pb, Zn, V, Cu, Co, Ni, Sr, Cr, Ga, Rb, Ba, U, Th, C org. et surface spécifique. une analyse factorielle a révélé un facteur de minéralisations regroupant Fe_3O_2, TiO_2, P_2O_5, PF, Pb, V, Ni, Ga, U, Th et surface spécifique qui s'oppose au facteur de richesse en silice (phénomène de dilution par le quartz et au facteur de réduction (FeO, C ...).

Le détail des analyses montre d'ailleurs aussi clairement que l'uranium n'est pas lié à la matière organique ni aux argiles, mais à la fois au fer ferrique qui forme essentiellement des enrobements d'hydroxyde sur des minéraux argileux, et en partie à des minéraux lourds (dispersion mécanique, probablement de la monazite).

La cartographie des fortes valeurs du facteur minéralisation, que ce soit par la fixation sur les hydroxydes de fer ou la dispersion mécanique par minéraux lourds, apporte une première indication des anomalies les plus significatives et la correspondance avec les zones d'occurrences est bonne. même si certaines anomalies ne sont jusqu'ici pas interprétées.

Une autre indication peut être tirée du rapport teneur en uranium/surface spécifique des échantillons anormaux. En effet, puisque la teneur en uranium est nettement due à une effet d'adsorption sur les hydroxydes de fer, la surface spécifique de l'échantillon, qui traduit à la fois l'abondance en hydroxyde et la capacité d'adsorption de l'hydroxyde lui-même, mesure correctement l'affinité du sédiment prélevé pour l'uranium. Le rapport teneur en uranium/surface spécifique indique donc la richesse en uranium véhiculé localement et non l'intensité de la fixation. Plus élevé est ce rapport, plus significative est l'anomalie. La cartographie de ce facteur définit ainsi, pour les valeurs supérieures à 0,5, les zones les plus proches des occurrences primaires.

Cette approche semble pouvoir être généralisée. Après des campagnes permettant de tester le rôle de l'adsorption pour tous les éléments relativement migrateurs susceptibles d'être absorbés. la correction des valeurs analytiques par la surface spécifique du prélèvement permet d'affiner le classement des anomalies et d'améliorer l'interprétation. Bien entendu, il ne s'agit pas de mesurer systématiquement la surface spécifique, mesure encore longue et chère. mais d'effectuer seulement cette mesure sur les prélèvements anomaliques. Une telle approche permet d'enrichir les techniques déjà utilisées d'interprétation des cas de prospections géochimiques difficiles.

Hydrogeochemical criteria of ore deposits exploration in siberian conditions.

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Our long term hydrogeochemical studies over many familiar deposits and mineralizations located in various geological landscape and geomorphological conditions demonstrated that hydrogeochemical anomalies occur in most of the cases, but the way the anomalies are formed may differ from one place to the other.

Indeed, the hydrogeochemical signature depends on the mineralization type as well as on geology, geomorphology and hydrology. So, for instance, in the Altai mountain region, and around mercury mineralizations, the hydrogeochemical anomalous dispersion train is rather short and poorly contrasted. On the contrary, in forested mountainous taiga landscape, the dispersion train is longer and the hydrogeochemical signature becomes more complex.

Our studies show the importance of factors as water composition, oxidation degree of the ore deposits, position of the mineralization with regards to the surface, etc. on the nature and intensity of the hydrogeochemical anomalies. Moreover, the data we have obtained are not in agreement with the classical scheme of hydrogeochemical dispersion. The characteristics of rock weathering and the water-rock interaction processes should be more taken into account.

Selection of significant anomalies is made easier by using multielement water analysis followed by a data processing sequence involving factor analysis. In such a way, various element associations are distinguished, corresponding to different origins : bed-rock composition, ore deposits, possible contaminations. These associations are used in selecting the significantly anomalous sites in different regions of Siberia.

Mercury in soil : a tool for exploration for hidden Pb-Zn ore deposit in sedimentary cover formation. Application in the "La Croix de Pallières" district (Gard - France).

J.F. Sureau
J. Letalenet
A. Coumoul

The Croix de Pallières deposit is located in the "Sub-Cevennes metallogenic province" on the southeast margin of the French Hercynian Massif Central. The deposit is made up of four lenticular bodies on the flank of a Tertiary horst at the junction of a major fault. The orebodies are more or less concordant with the Liassic dolomitic host rock (Hettangian to Sinemurian). This deposit is classify as epigenetic due to per ascensum circulation of hot brines.

Until 1971, 100,000 tons of metal have been extracted, essentially Zn, Pb (Zn/Pb=4) and Ag, Ge.

The detection of unusual trace elements (As, Sb, Tl, Hg) in the main ore minerals (pyrite, galena, sphalerite) and gossans as well as in surrounding dolomitic rocks testify the foreign contribution of mineralized hydrothermal fluids. Mercury is mainly located in iron and zinc sulfides. So, mercury can be used as pathfinder in soil geochemical exploration of hidden mineralization.

This approach is employed at a local scale southwest of La Croix de Pallières mine. The area was selected after a regional multielement geochemistry. The control led to a Pb-Zn-Ag-As-Sb soil anomaly.

The analysis is performed on the minus 0.125 mm fraction of 565 soil samples taken on a 100 x 50 sampling grid.

Mercury is analyzed by using an atomic absorption spectrometer (Scintrex HCG-3) after :

- sulfo-nitric chemical extraction and mercury reduction by $SnCl_2$ to cancel the influence of organic matter or sulfide. The mercury vapor is retained on "Syrosorb" before pyrolysis at 450 degrees ;

- direct soil pyrolysis at 600 degrees.

The comparison between the two techniques shows a good agreement. This kind of residual soil allows direct pyrolysis and the analytical cost is quite lower.

Programmed heating was tested at 200, 300, 400, 600 and 750 degrees. At 400 degrees about all the mobile mercury is released from iron oxides.

The Hg values distribution is log-normal between 20 and 700 ppb. Mapping of mercury values shows haloes along the Hettangian formation in good relationship with the other As-Sb-Ag pathfinder elements. Moreover Hg shows an important east-southeast and west-northwest trend which corresponds to a normal fault. So, in this case, mercury can be an indicator of primary or secondary dispersion from a hidden mineralization.

Exemple d'utilisation combinée de la mercurométrie et de la géochimie en roches pour la détection de colonnes minéralisées du filon à Zn-Pb de St-Salvy (Tarn), partiellement recouvert par des dépôts tertiaires.

G. Verraes

La mine de St Salvy exploite un filon, connu sur une dizaine de km d'extension et minéralisé sur 3 000 m environ. La partie ouest de la zone minéralisée est surmontée d'une auréole géochimique anomale en sol, qui dépasse 2 000 ppm en plomb et 10 000 ppm en zinc (travaux BRGM, 1965).

Par contre aucune anomalie significative ne marque la partie Est de la mine (Le Rouquis) par suite, soit d'un enfouissement des panneaux minéralisés, soit de l'existence d'un recouvrement d'argiles à graviers tertiaire.

Ainsi, parallèlement à la microgravimétrie, deux techniques géochimiques, la mercurométrie en sol et la géochimie des chapeaux de fer ont été mises en oeuvre pour la recherche de nouvelles concentrations métalliques.

a) La mercurométrie en sol

Pour l'application de la mercurométrie, dans le cas de St Salvy, nous nous trouvions confrontés à deux problèmes :

- une très grande hétérogénéité des sols en matière organique,
- un très faible pourcentage de mercure piégé (de 0 à 22 ppb) avec un important effet de pépite.

Il fallait donc trouver une méthodologie de préparation d'échantillon qui permette à la fois de lisser l'effet de pépite et de mesurer des teneurs en mercure au 1/10e de ppb.

Après une série d'essais au laboratoire de la mine de St Salvy une méthode de traitement d'échantillons respectant ces préoccupations a été mise au point et appliquée avec succès, elle consiste à :

- prélever dans des bocaux de verre à 50 cm de profondeur des échantillons de 200 à 250 gde terre brute,
- distiller ces matériaux à 450° C sous un courant d'air purifié pendant 5 h,
- capter le distillat dans un mélange acide et oxydant pour fixer le mercure et oxyder les matières organiques présentes dans la terre.

Dans les échantillons ainsi préparés le mercure est sous forme stable et peut rentrer dans les circuits d'analyse des polluants industriels.

L'analyse s'est faite par absorption atomique en vapeur froide avec un appareil "Perkin-Elmer" 500 AA doté d'un Mercury hydride System MHS 20.

La sensibilité de le mesure sur le distillat était de 0,5 ppb ce qui rapporté à la masse de l'échantillon donnait une sensibilité largement suffisante de l'ordre de 0,02 ppb.

Les résultats de cette étude portant sur 1 155 prélèvements ont montré :

- la parfaite superposition des anomalies en mercure avec les minéralisations connues,
- l'existence de zones anomales inconnues qui se superposaient le plus souvent à des anomalies sur chapeaux de fer,
- l'existence d'anomalies "de fuite" le long de failles transverses au filon,
- la possibilité d'utiliser la méthode avec des couvertures de 15 à 30 m de morts-terrains argileux,
- l'obtention d'un seuil de sensibilité effectif de 0,1 ppb,
- une reproductibilité de l'ensemble de l'opération à partir de plusieurs prélèvements successifs autour d'un même point (écarts entre les analyses inférieures à 15 % de la teneur moyenne).

b) La géochimie des chapeaux de fer

L'affleurement du filon de St Salvy est extrêmement discontinu à la fois dans le sens longitudinal et dans le sens transversal. Les pointements silicifiés qui affleurent représentent une partie quelconque d'une caisse de 40 m de puissance alors que le minerai se concentre dans une des épontes. Ces affleurements ont des faciès très divers qui se manifestent par des teneurs en fer allant de quelques ppm à 40 %.

Les échantillons de chapeaux de fer ont été analysés par spectrométrie multiéléments.

Le traitement des données, réalisé sur micro-ordinateur IBM-PC a consisté à déterminer statistiquement par rapport à une loi log-normale, les seuils d'anomalies à normer les teneurs des traces métalliques par rapport au fer et à étudier les échantillons de segments filoniens de longueur homogène.

Pour chacun de ces segments, une "signature géochimique" a été établie à partir des pourcentages d'échantillons anomaux en Pb, Cu, Ag/Cu, Pb/Fe et Ag/Fe. Pour caler la méthode on s'est appuyé sur quatre segments qui surmontent des minéralisations sulfurées localisées respectivement à 125, 150, 175 et 200 m sous la surface.

Une évolution des "signatures" a été ainsi mise en évidence ; elle montre une relation nette entre la raréfaction des anomalies et la profondeur du contact minerai sulfuré-minerai oxydé.

Ces valeurs, comparées à celles de la mercurométrie ont permis de localiser des portions de filon probablement minéralisées.

Un premier contrôle par sondage a été effectué sur une des zones ainsi découvertes et considérées comme stérile jusqu'alors. Ce test a démontré l'exactitude du pronostic ; depuis celui-ci a été confirmé par des travaux miniers ayant recoupé un minerai riche à la profondeur prévue.

Importance of understanding geochemical processes vis-à-vis environmental consequences.

R. Watters

In the Alligator rivers region of the northern territory ; little formal work has been done to evaluate the environmental consequences of, for example, direct discharge to creeks or land application of excess mine water, contaminated or not.

What constitutes contamination is a matter for some speculation and not without political overtones. Fears of possibly adverse environmental consequences of almost anything associated with uranium mining and its ancillary works have been raised by vested interest groupes, often without foundation. Nevertheless, the main causes for concern are trace quantities of uranium and its natural daughter products, as well as base metals, which although not present in great amounts, are remembered for the environmental damage caused at rum jungle.

Decisions have frequently been delayed or obfuscated on the grounds of uncertainties or the need to carry out further investigations. When much of the information sought was available in one form or another in the literature of exploration geochemistry. In particular, the understanding of trace element speciation and carriage mechanisms is directly pertinent to predictions of the environmental consequences of carrying out particular acts in the vicinity of the renowned Kakadu national park.

In the past ten to fifteen years, a vast amount of research has been published, much of it of identical usefulness to the explorationist and the environmentalist. Mechanisms such as adsorption and coprecipitation of heavy metals by ferric and manganese hydroxides such as particles or coatings are of vital importance in assessing the likelihood of environmental impacts and their seriousness.

The importance of partial or sequential extractions in elucidating speciation mechanisms has often been overlooked in environment considerations, whereas literature of exploration geochemistry has, from its earliest beginnings, recognised their significance.

The ranger uranium environmental inquiry, chaired by Mr. Justice Fox, did not have access to a qualified applied geochemist and could not therefore take valid submissions on the subject. As a result, several conservative decisions, laws and regulations were promulgated. These decisions encompassed water release, construction materials, water retaining structures, occupational hygiene, monitoring programmes and waste management.

The relevant sub-sections of applied geochemistry as well as of the other disciplines have, in any case, evolved rapidly in the last decade and many of the expressed fears for mining in or near Kakadu may now be laid to rest.

The conclusion, as well as northern territory government policy, is that mining can take place safely in or near a national park and that geochemistry is a useful predictor of possible impacts.

Thème 7 : DEVELOPPEMENTS ANALYTIQUES ET TECHNIQUES ISOTOPIQUES

Topic 7 : ANALYTICAL DEVELOPMENTS AND ISOTOPIC TECHNIQUES

L'analyse des platinoïdes en prospection géochimique : présent et futur.

M. Borsier
A. Batel

L'intérêt croissant de la recherche des éléments de la mine de platine nécessite la mise au point de techniques analytiques qui doivent :

- Avoir un coût de revient aussi bas de possible.
- Pouvoir être réalisées sur de grandes séries d'échantillons.
- Utiliser un poids d'échantillon représentatif du prélèvement en tenant compte de son hétérogénéité.

Une investigation des différentes voies possibles a été réalisée au niveau de la préparation des échantillons d'une part et de la mesure d'autre part.

PREPARATION DES ECHANTILLONS

Trois voies sont possibles à ce niveau :

- Fusion plombeuse avec incartation à l'or, avec attaque eau régale du bouton.
- Fusion au sulfure de nickel.
- Attaque combinée par voie acide destruction des résidus réfractaires par fusion au peroxyde de sodium et précipitation des platinoïdes au tellure.

Les résultats obtenus par ces diverses voies ont montré :

- que l'osmium n'est pas totalement récupéré dans les trois attaques réalisées ;
- que l'iridium n'est pas totalement récupéré par la voie fusion plombeuse.

Après récupération dans chacun des cas les métaux sont remis en solution pour les analyses par attaque à l'eau régale.

MESURE

1) Actuellement la mesure est réalisée par absorption atomique en four graphite. On constate que la préparation a une influence sur la mesure. en particulier l'intraînement de nickel dans la fusion au sulfure du nickel induit des interférences difficiles à maîtriser.

Pour les deux autres préparations la mesure des différents éléments s'effectue soit par calibration directe. soit par la méthode de ajouts dosés. Les conditions analytiques optimales sont présentées table 1 et les limites de détection varient de 5 à 10 ppb selon les éléments.

2) Les développements actuels très rapides de la technique de couplage ICP/MS permettent d'envisager dans un futur proche une amélioration très nette de la limite de détection des platinoïdes après l'une ou l'autre des préparations mentionnées dans la première partie. Les limites de détection que nous avons obtenues en collaboration avec l'USGS sont actuellement inférieures à 1 ppb.

Application of multi-element inductively coupled plasma atomic emission spectrometry (ICP-AES) in hydrogeochemical mineral exploration.

I.B. Brenner
M. Beyth
L. Halicz

Saline waters from thermal springs and seepages located along the western margin of the dead sea rift are analysed by simultaneous multi-element inductively coupled plasma-atomic emission spectroscopy (ICP-AES). ICP-AES is shown to be an efficient analytical tool for hydrogeochemical exploration due to its accuracy, detectability, large sample throughout and multi-element capability which facilitates interpretation of the water chemistry and geohydrology, thus assisting in discriminating between true and false anomalies.

Gold exploration at Tennant Creek, Australia, using lead isotopes.

B.L. Gulson
R.R. Large
P. Porritt

Lead isotope analyses have been undertaken as part of a program to evaluate the potential use of geochemical methods for exploration in the Tennant Creek goldfield, where previous emphasis has been with magnetic geophysical methods. Economic gold, copper and bismuth mineralization usually occurs in magnetic magnetite-chlorite lenses or pods ('ironstones') which may be only 30m across. Several hundred ironstones are found in the Tennant Creek field of which only 9 have been significant producers.

Despite complications arising from the low lead and relatively elevated uranium contents of the ore, lead isotopes in drill core material are able to discriminate between economic magnetic ironstones and barren ironstones of similar mineralogy and geochemistry. A target signature for the thorium-derived lead isotope ratio, $^{208}Pb/^{204}Pb$, is specific for lode mineralization although it is not possible to discriminate between gold-rich and copper-rich lodes. The target signature is found not only in the central gold-rich magnetite-chlorite zone, but also in the outer talc-magnetite and carbonate zones. This offers an almost two-fold increase in the size of the target.

The lead isotopic signature is retained in hematite-rich surface material and it appears possible, at this stage of the research, to discriminate between surface ironstones derived from magnetic barren and fertile ironstones.

Magnetite and hematite shales (B.I.F.'s) throughout the field do not appear to have been the local source for the economic lodes. Differences in the lode signature and these barren shales range from -20 to -40 % in the channelways for the ore fluids as the target signature is discernible for up to 50 m along the hematite shale horizons from the outer chlorite zones of signature is not detected at about 5m from the magnetite-chlorite zone. These differences offer a further enhancement in the dimensions of the target.

A discrimination between weakly-mineralized (either copper or gold) and barren magnetic ironstones is equivocal at this stage.

The lead isotope data are consistent with an epigenetic origin for the magnetic ironstones.

A comparison of lead isotopic measurements on exploration type samples using ICP and thermal ionisation mass spectrometry.

L. Gulson
A. Meier
E. Church
J. Mizon

The main limitation on more widespread use of lead isotopes in mineral exploration has been the cost of the analyses. Thermal ionisation mass spectrometry requires a sophisticated and time-consuming separation of the lead but gives proven high precision lead isotope ratios for all types of samples.

Inductively coupled plasma (ICP) mass spectrometry offers a simple, rapid and cheaper alternative for lead isotope measurements but comparisons of the two techniques for real exploration-type samples such as gossans, soils and complex ores have been lacking. On the other hand, published data and additional material presented here for international lead standards and lead-rich materials such as galena, are remarkably precise and within the +/-0.2 % (2 sigma) limits claimed for the 206Pb/204Pb ratio.

Lead isotope ratios were obtained by both methods on the same HCl/H_2O_2 extracts of Fe and Mn oxide coatings from stream pebbles. Reproducibility of the thermal ionisation data is excellent and within the limits of +/-0.1 % (2 sigma) for the 206Pb/204Pb ratio. Reproducibility of the ICP data is considerably worse than the thermal data and there is a systematic bias towards higher 208Pb/204Pb and 207Pb/204Pb ICP ratios. Because of overlap of the 207Pb by the 206Pb and 208Pb peaks by ICP, the data for the 207Pb/204Pb are not considered reliable.

Assessment of over 500 exploration case studies using lead isotopes shows that less than 20 % could have been achieved using ICP mass spectrometry and most of these are for uranium exploration. High precision and accurate isotope ratios are essential for using lead isotopes in most mineral exploration programs and particularly in ore genesis investigations. Until more reliable data can be obtained on real samples, the ICP spectrometer is not a viable alternative to thermal ionisation methods.

Instrumental neutron activation analysis (INAA) as an analytical technique for gold and platinum-group Element exploration.

E.L. Hoffman

The exploration geologist or geochemist must select a suitable geochemical sample media in his quest for the elusive gold or platinium group element deposit. These sample media include rocks, soils, heavy mineral concentrates (from overburden drilling and panned concentrates), humus, vegetation, water, lake bottom sediments, stream sediments etc.. The nature of the media available, cost, turnaround time, and accuracy will usually affect the geochemit's choice.

A wide variety of techniques employing INAA available depending on the type of material to be analyzed, and the type of information required. These techniques are summarized by a method listed in table 1 which will be continuously referenced.

Rock and soil

Methods 1-5 describe various neutron activation analysis techniques which include both fire assay and instrumental methods. Size of sample analyzed ranges from less than 1 gram to as large as 500 grams. Detection limits achievable are as low as 0.1 ppb for radiochemical gold determinations.

Method 3 is a completely intrumental technique which allows the determination of gold and simultaneous determination of 27 other elements on a 30 gram aliquot of sample. The multielement nature of this data can provide a wealth of geological and geochemical information for both gold and platinum group metal exploration.

Glacial till or panned concentrate

One of the preferred techniques for gold exploration in glaciated areas involves overburden drilling. Non-magnetic heavy minerals are usually concentrated and analyzed. The size of the sample dictates the necessity of analyzing the entire sample usually by INAA (method 6). Some exploration programs utilize a very fine size fraction of the till typically finer than -250 mesh. Methods 1, 2 or 7 are applicable to this type of exploration depending on required detection limits.

Vegetation and humus sampling

In areas of overburden, biogeochemical prospecting may provide the most effective and lowest cost geochemical exploration for gold. The rapid increase in the use of biogeochemistry is partially a result of the development of low cost, rapid INAA techniques capable of detecting directly background levels of gold and other potential pathfinder elements in the vegetation. Understanding of the technique as it relates to gold exploration has also increased dramatically in the last few years.

Water and lake bottom sediments

Specific analytical procedures have been developed for these matrices and are listed as methods 11 and 12 for water and methods 13-15 for lake bottom sediments.

The relative merits of each of the techniques along with precautions and the advantages and disadvantages of each of these techniques will be described.

Isotope signatures (Pb-Sr) of polymetallic mineralization in the Ariab district (Red Sea Hills, northeast Sudan).

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F. Cottard
Y. El Samani
G. Récoché
J.Y. Calvez
Y. Deschamps

Ariab district belongs to a volcanosedimentary complex of Upper Proterozoic age which extends over an area of 250 kilometers. It comprises at least seven polymetallic sulphide orebodies of exhalative origin with which economically important gold-bearing silica-barite layers are associated.

One hundred determinations of lead isotopes were made on gossan samples, sulphides and silica-barite bodies in the district. The result obtained were compared with those of multi-element geochemistry which allows to distinguish the gossans associated with the sulphide bodies and silica-barite bodies.

The variety of isotope signatures taken from the Hadal Auatib gossan shows that it formed at the expense of at least three distinct sulphide ore bodies (206Pb/204Pb respectively of 17.79, 17.92 and 18.04). These three orebodies were strongly affected by late tectonic episodes and each one is cut across several times in the same drill hole.

Sulphides Pb isotopes confirm the existence of several orebodies at Hassai. The relationships between sulphide and silica-barite mineralization are inferred by the combined use of Sr and lead isotope geochemistry.

Generally, the results of Pb isotope geochemistry corroborate the field observations in the differenciation and distribution of the different mineralized bodies that can be grouped into families.

The different isotope signature identified at the scale of the region (206Pb/204Pb = 17.30 at Oderuk, 18.32 at Adaïamet) and between neighbouring bodies (Hadal-Auatif, Hassaï) indicate the contributions of different metal sources (mantle, old continental crust), which is in agreement with the particular geological history of the region. The chronological intervals between the emplacement of the various mineralized bodies are necessarily short and their influence on the isotope variations is negligible.

Utilisation des méthodes d'extractions chimiques sélectives pour la prospection géochimique en milieu latéritique.

H. Martin
F. Sondag
J.N. Bolle

L'étude des associations entre éléments dans les échantillons prélevés en contexte latéritique indique fréquemment une liaison globale importante avec le fer. Ce type d'association est toutefois de peu d'aide puisque les diverses phases ferrifères (goethite, hématite) sont des constituants essentiels, voire uniques, de ces échantillons.

Afin de progresser vers une meilleure connaissance de la localisation des métaux dans les échantillons, des études par extractions chimiques sélectives ont été réalisées sur des échantillons prélevés dans différents environnements géologiques en zone intertropicale. De plus la cinétique de la dissolution des différentes phases a été étudiée en détail.

Deux environnements où une altération latéritique intense existe seront présentés :

- en Sierra Leone, un complexe amphibolites-granite, ce dernier étant minéralisé en Cu et Mo ;
- au Burundi, une minéralisation nickélifère associée à des roches ultrabasiques (péridotite).

L'étude a été menée sur des échantillons de surface ainsi que sur des sondages. Les principaux résultats font ressortir d'une part le peu d'importance des produits ferrifères amorphes tant dans les horizons superficiels que dans les niveaux argileux profonds et d'autre part une association des éléments métalliques liés à la présence des minéralisations avec les hydroxydes de fer cristallins dans la partie superficielle du profil d'altération. Vers le bas du profil, ces mêmes éléments ont tendance à être exprimés davantage sous forme silicatée, que ce soit en association avec des phyllosilicates ou dans des silicates résiduels.

L'examen des résultats des études cinétiques fait apparaître dans plusieurs cas deux pics sur les courbes de vitesse de dissolution des oxy-hydroxydes de fer cristallisés. Ces deux pics résultent de la dissolution successive de phases minérales distinctes qui sont caractérisées par un état de cristallinité et/ou une composition minéralogique différentes. L'existence de ces phases doit résulter de la superposition de processus d'altération ayant affecté la séquence. L'attribution d'éléments indicateurs à l'une ou l'autre de ces phases permet dès lors de mieux préciser le chemin parcouru par ceux-ci et notamment d'apporter des informations quant à leur caractère résiduel éventuel. Ceci peut constituer un appui important pour le succès de la prospection géochimique.

Thème 8 : TRAITEMENT DES DONNEES ET MODELISATION

Topic 8 : DATA PROCESSING AND MODELING

Intérêt de l'évaluation quantitative des anomalies géochimiques en sol, relevées en prospection détaillée.

J. Barbier

L'évaluation des anomalies géochimiques en sols est un moement important de la prospection minière : c'est, en effet, une des méthodes employées pour la sélection des cibles de sondages et, par suite, un élément de décision dans les choix d'investissements. Pourtant, c'est un aspect très peu abordé dans la littérature occidentale, tout au moins d'un point de vue quantitatif ; les travaux sont le plus souvent descriptifs, et accordent une large part au tracé et à l'interprétation des courbes isoanomales. Cependant, les auteurs soviétiques ont proposé diverses manières de chiffrer la valeur des anomalies en sol.

Ainsi, parmi les formules de Solovov, l'une d'elles conduit à une mesure qui s'exprime en m^2 %, c'est-à-dire en termes de dimensions, une mesure homogène à une surface. Rapportée à une épaisseur de 1 m de sol de masse volumique d (ou tonnes /m^3), cette mesure s'exprime en m^2 % m.t/m^3 : elle est donc homogène à un tonnage. De ce point de vue, elle peut être rapprochée de la notion de tonnage au mètre d'approfondissement, familière aux mineurs.

Aucune comparaison systématique ne semble avoir été publiée entre l'évaluation quantitative des anomalies géochimiques en sol d'une part, et les résultats des travaux miniers ultérieurs, d'autre part. A cet égard, les résultats obtenus en France sont intéressants ; en effet, prospection et reconnaissance minières préliminaires par travaux souterrains sont, pour une part, financées sur des fonds publics (Programme d'Inventaire national), et le niveau de confidentialité des résultats est donc bas. La comparaison sur différents gîtes sulfurés est instructive et montre que, pour certains métaux, l'évaluation des anomalies en sol (chiffrée en tonnes) est du même ordre de grandeur que les estimations en profondeur par travaux miniers. En d'autres termes, la géochimie en sol permettrait une évaluation, grossière certes mais utile, du tonnage d'approfondissement au niveau de la surface topographique : cela constituerait une vérification a posteriori des formules de Solovov.

Bien entendu, les phénomènes de lessivage et de mobilisation dans la zone d'oxydation doivent être pris en compte. La quantité de métal relevée au niveau du sol est représentative de la zone d'oxydation, et non du minerai primaire ; à cet égard, les calculs sur des métaux mobibles tels que Zn, U ... sont de moins d'intérêt que sur des métaux plus stables dans des conditions de surface, tels que Pb, Ag ou Au.

La question des gisements aveugles mérite d'être posée ; par définition, ce sont des gisements n'affleurant pas : il n'y a donc rien que de normal à ce que le tonnage en métal au niveau de la surface topographique soit faible ou nul, et qu'il en soit de même des anomalies géochimiques correspondantes. Cela ne doit pas remettre en cause une méthode d'évaluation quantitative des anomalies géochimiques en sol ; simple procédé de calcul analogue à un échantillonnage minier, cette technique est une technique d'interpolation. Ce n'est pas une méthode d'extrapolation qui permette de prévoir en profondeur l'évolution, en géométrie comme en teneur, des gisements primaires.

A l'échelle du globe, la démarche n'est probablement pas valable dans les zones d'anciennes glaciations, à cause des dépôts allochtones. En dehors des exemples français de zones tempérées, quelques cas en zone désertique ou en zone équatoriale permettent d'envisager, là aussi, l'emploi possible des techniques d'évaluation quantitative sur les anomalies en sol.

Pour terminer, un système d'abaques est proposé pour permettre la comparaison facile d'anomalies géochimiques réalisées à des mailles de prélèvement différentes, entre elles ou avec des anomalies-types de gisements connus.

Geochemical prospecting in complex sample media. Multivariate data analysis of indirect observations.

K.H. Esbensen

A. Steenfelt

Geochemical exploration in secondary environments represents a particular manisfestation of indirect observation. Geochemical anomalies in complex sample media reflect indirect dispersion signatures, generally much disguised by secondary or higher order mechanical and physico-chemical processes such as mixing, comminution, dilution, (re)transportation and wheathering. Such complexities often make a thorough understanding of the origin of any particular sample type (as well as individual samples) illusory. The objective of data analysis in this context is to decompose the in toto geochemical data into a meaningful "signal" particularly useful for prospecting, shredding away irrelevant "noise". Traditionally emphasis has been on characterising anomalous samples, although by their varied nature, they make up a very mixed set of samples in most situations.

Exploration geochemistry and lithogeochemistry commonly rely on a multielement chemical analytical approach, whereas subsequent data analysis and interpretations are still too often carried out in the univariate regime. Considerable efforts are spent trying to define operative single-element thresholds in order to delineate geochemical anomalies in a variety of statistically dogmatic ways, by no means always closely related to the geological problems at hand. Consideration of the nature of exploration geochemical data reveals that more information components are looked for in any individual datum, than can be accommodated by the available number of degrees of freedom in this univariate approach.

Experience gained during the last decades of practical exploration has clearly shown that statistical as well as geographical and geochemical anomaly patterns very often are multielement signatures.

By using multivariate bilinear projecting facilities (in the present case principal components modelling), it is simultaneously possible both to define a regional background data model and quantify a concept of a multivariate geochemical anomaly. This type of data analysis is guided very strongly by geological interaction in the data analytical stage, in which emphasis is on modelling (and understanding) the background population(s). Indeed for the multivariate approach, the processes responsible for the distributions of covarying elements in the background can often be more open to geological interpretation than are the looked for (sub)population(s) of anomalous samples, especially when coupled with suitable geographic plotting facilities. Geochemical anomalies are subsequently delineated as samples with significantly deviating residuals with respect to these background modes. The salient "trick" of pragmatic indirect observation in prospecting geochemistry lies with this background understanding : essentially everything that is not anomalous gets to reside here. As long as the multivariate threshold can be defined, it does not matter whether the genesis of the background can be understood in full details or not.

This multivariate partioning of exploration geochemical data into a systematic model (background and/or distinct anomaly subgroup) and an unsystematic residual complement (anomalies or noise) has parallels within many other types of indirect geological data sets.

More advanced types of bilinear data analysis, conceptually also based on the above philosophy, e.g. two-block PLS-regression and -prediction, will be illustrated in another paper dealing with regional geochemical data from West Greenland. This contribution presents in detail the PLS-method from the above data analytical point of view, as well as selected geochemical examples.

The Chi-square Plot : a tool for multivariate outlier recognition.

R.G. Garrett

In large multi-element regional surveys traditional threshold values of the form that define, for example, the top 2 % of the data for each element as worthy of further investigation have led to the generation of inordinately large lists of geochemical samples for detailed study. This problem is compounded when a number of geological and secondary environments exist of sufficiently different character that separate thresholds should be estimated for each. Additionally, using single element thresholds for multi-element surveys can, in certain circumstances, lead to individuals of an obviously out-of-character nature not being recognized.

The requirement exists for a procedure which can simultaneously handle all the elemental data for a single geological or environmental population. Such a procedure would then identify those individuals that are truly multivariate outliers, and therefore possible geochemical anomalies, or identify some user defined percentage of the most extreme members in the population for further investigation.

Approaches to this problem in the recent past have commonly used a principal components analysis or regression model as their basis. Both of these approaches, as indeed do all approaches, have a common problem in that the outliers that are being sought can badly distort the initial analysis. In some cases to such an extent that the truly anomalous individuals are not detected and that truly non-anomalous samples appear anomalous. In addition, regression approaches have the further problem that there may be outliers in both the response and predictor variables and that they may have dissimilar error structures.

A relatively simple approach to this problem would be to plot a multivariate cumulative probability plot where each geochemical sample is described in terms of a single value. The values would be ordered from smallest to largest and suitably plotted. The resulting diagram would be interpreted much as a univariate probability plot where the presence of more than one "straight-line" segment is evidence of multiple populations, and outliers, as individuals or in small groups, are separated from the remaining data by gaps on the plot.

Such a diagram is the chi-square plot where ordered values of Mahalanobis Distance are plotted against corresponding values of the chi-square distribution. These values of chi-square are computed as a direct function of the rank order and the number of degrees of freedom, which is equal to the number of variables. A true multivariate normal distribution will plot as a straight line on such a diagram.

The Mahalanobis Distance is the multivariate analogue of the more commonly known standard normal deviate or standard score. In the standard score the distance from the mean is scaled by the standard deviation, large values indicate increased distance from the mean. The Mahalanobis Distance is the distance of a sample from the centroid of the data scaled by the covariance matrix, which is a measure of the data interrelations and variability.

Clearly, the position of the centroid and the values of the covariance matrix are themselves subject to modification by the very outliers being sought. Therefore some sort of robust start is required if true outliers (anomalies) are to be detected. To carry this procedure out an interactive computer graphics programme is utilized. After inspection of the initial plot, successively higher numbers of samples with extreme values of Mahalanobis Distance are trimmed, i.e., removed, and identified, then the centroid and covariance matrix are computed and used to determine the Distances for all samples prior to presentation of a new plot. After several trials it becomes clear which individual samples have to be trimmed to generate a relatively stable covariance matrix and centroid. Using these estimates as a starting point a chi-square plot is presented to the user who then uses the graphics cursor to enter a cut-point. Extreme values beyond this cut point are temporarily deleted from the procedure and their identifiers displayed. A new centroid and covariance matrix is computed from the now graphically trimmed data and a new chi-square plot for only the remaining data presented. If outliers are still apparent they are then trimmed, their identifiers displayed and a new centroid and covariance matrix computed. This procedure continues iteratively until the user is finished, commonly at the point where all obvious outliers identified by this procedure have been trimmed and a single population of "background" individuals remains. Finally, a list of all detected outliers is presented ranked by their Mahalanobis Distances using the "background" centroid and covariance matrix. It must be stated that although geochemical samples have been identified as outliers, in terms of the resulting background population, there is no guarantee that they will be truly anomalous and related to mineral occurrences. Only a careful study of the outliers in terms of their geochemical and spatial context will provide the final evidence and interpretation.

If no outliers, or only very few, are present the user can select for study some percentage of the multivariately most extreme background samples. Again these require inspection in terms of their geochemical and spatial context to determine if they are of particular interest to the study underway.

The procedure outlined above is referred to as GAIT, Graphically Adaptive Interactive Trimming. It has the advantage that the percentage of trimmed data depends upon the data themselves as presented in the chi-square plots, thus the method is data based and not dependent on some prior notion that 5 % or 10 %, ect., of the data should be trimmed. The GAIT software was developed in 1981 and has been successfully used since that time on a number of geochemical data sets. Currently it is implemented within IDEAS, a colour interactive graphics package which is being developed in the Exploration Geochemistry Subdivision of the Geological Survey of Canada.

Data analysis and geochemical mapping for the regional stream-sediment survey of Austria.

H. Kurzl

During the past years a concept for data analysis and mapping for the geochemical stream-sediment survey of Austria has been developed. Based on this study a data processing system has been established, which consists mainly of inhouse developments, concerning particularly robust-resistant statistics, interactive graphics and automated mapping. One of the basic principles of the concept is, that the resulting products can be easily interpreted by various kinds of users, especially from mineral exploration but also from geological as well as environmental sciences.

Started in 1978, the survey was limited to areas underlain by crystalline rocks, excluding the calcareous Alps and the young sedimentary basins. Covering 40,000 km^2, which is about half of Austria, 30,000 samples were collected and analysed for 36 elements. Recognizing the special problems in interpretation of stream-sediment geochemical data, an attendant orientation study has been carried out during the past years. After establishing practical detection limits and sampling and analytical errors, data analysis and geochemical mapping were initiated.

The first project concerning data interpretation, covered approximately 10,000 km^2 and was finished at the end of 1985. An a priori area was selected by dividing the whole area into regional geological-tectonic domains to be investigated separately. Each region was represented by several thousands of stream-sediment samples, on an average about 3000. The initial task was to establish data reliability in connection with a comprehensive raw data documentation, consisting of univariate statistics, graphical data batch summaries for each element and documentation of the raw data by point source maps. Instead of conventional statistics, robust-resistant techniques derived from Exploratory Data Analysis (EDA), are used. One dimensional scattergrams combined with density traces and boxplots proved to be very useful, supplying the geochemist with the essential information on single element behavior in a straightforward and quick way. At this first stage of data analysis already a resistant EDA-technique based on order statistics is used to define outliers (anomalies). The resulting model-free distribution parameters generated resistant class-intervals. This method offers a procedure for a more objective class-selection and was combined at that stage with EDA-symbols to produce single element point source maps. It also proves to be very effective in all further steps of data analysis, where results in form of derived variables have to be mapped.

Due to rapidly changing lithology, alpine type geological-tectonic domains do not represent homogeneous geochemical populations. Therefore the next step in data analysis is dedicated to the definition of regional geochemical groups, as a base for the estimate of regional element levels and variations. Robust principal component analysis has been very useful in discriminating elements of regional and local variability. After an element screening, scores of the first eigenvector, supposed to carry the largest multivariate variability, were mapped, to get a first impression of regional differences. Based on this interactive work a selection of element combination are used in different cluster-techniques. The best results can be obtained by the application of the MST-method (minimal spanning tree), which allows the visual recognition of natural clusters on graphical displays. A geochemical interpretation of the results is achieved by the bi-plot method, whereby the variance and correlation of the elements used as well as the individual samples (groups) are displayed in the respective vectorspace. Minor corrections to misclassifications and adjustments to geology are made interactively in order to generate geochemical groups, characterized by a homogeneous geographical appearence. To get a measure of the accurateness of clustering, besides the visual appreciation, simultaneous tests using the Bonferroni-confidence intervals have been successfully introduced.

The estimate of regional element behavior is made within the established groups separately, using geostatistics. Regional composite maps, combining the independently estimated geochemical surfaces, are labeled and standardized according to the boxplot parameters. Until now this has been done for elements of economic interest only. Advantages of this procedure are the possibilities of representing clear cuts (natural disturbances) in the geochemical surface, which might be due to facies changes. lithology, tectonic faults or environment. Additionally it enhances mapping of regional variability and allows the representation of broad regional anomalies. A side product are residual maps, reflecting local deviations from the background.

Further detailed analysis is dedicated to a subdivision of the regional groups. This is carried out with the above-mentioned methods and seems to be absolutely necessary if detailed formal statistical analysis is to be applied to data batches, deriving from areas with complex local lithology. For this subgroups univariate classical as well as robust-resistant statistics are calculated, leaving the interpretation to the specific users in line to their different intentions. For those elements of special interest or exhibiting interesting anomalous patterns, multivariate methods were introduced for detailed evaluation. One of the main tasks is the discrimination of element enrichments, due to lithology and/or environmental influences (false anomalies) in contrast to those due to mineralisation processes. Additional low level cryptic anomalies can be detected by the interpretation of residuals. Methods routinely used are a robust version of canonical correlation analysis and robust regression. In many cases anomalous patterns could be removed. Sometimes, however, a distinct enhancement of the geochemical contrast can be obtained, indicating areas of special interest.

Le traitement multi-données : application à la sélection des zones à forte potentialité aurifère dans le sud de la Guyane Française.

J.Cl. Lasserre
J. Testard
B. Coste

Entre les parallèles 3° et 3°30 N, le socle de la Guyane Française est constitué par une ceinture de roches vertes (Série Paramaca du Protérozoïque inf.) encadré par des granitoïdes et migmatites anatectiques et des intrusifs acides ou basiques.

En 1976, les anomalies aéromagnétiques ont été localisées et étudiées au droit des formations volcano-sédimentaires.

Entre 1977 et 1982, et dans le cadre des travaux de l'Inventaire Minier de la Guyane, ce secteur de 12 000 km^2 a été couvert par des prospections comprenant en particulier un échantillonnage géochimique en sol (maille 2 000 x 500 m) ou en sédiment de ruisseau (0,7 à 1,6 éch./km^2) et un échantillonnage alluvionnaire (0,4 à 1,4 éch./km^2). Les échantillons géochimiques ont été analysés en spectrométrie d'émission (quantomètre) (analyse multi-élémentaire sur 34 éléments) et pour l'or.

La cartographie géologique de A. MAROT (1976-1982) sur le Sud de la Guyane s'était déjà appuyée sur l'interprétation des résultats analytiques géochimiques et minéralogique, campagne par campagne.

Afin de réaliser une étude régionale sur l'ensemble du secteur, une fusion de tous les fichiers informatiques de données a été réalisée, aboutissant ainsi à 2 fichiers : l'un de 12 000 analyses multiélémentaires (34 variables) et l'autre de près de 5 300 études minéralogiques de concentrés alluvionnaires.

Le sujet de cette synthèse était une hiérarchisation des nombreuses indications aurifères (géochimique ou alluvionnaire) par la mise en évidence de critères, réputés favorables à l'apparition de concentrations aurifères primaires : zones de fractures, processus hydrothermaux, séquences lithologiques particulières, intrusifs, etc.

L'outil utilisé est "Synergie" qui est un logiciel interactif graphique permettant le traitement simultané de données cartographiques d'origines diverses.

Le traitement des données multisources a été ramené par ce logiciel à un problème de traitement d'image grâce à une "pixellisation" (à la maille de 1 km x 1 km) des réseaux d'échantillonnage initiaux. La base ainsi créée comporte 12.650 pixels (projection des observations sur une grille à maille carrée). Ces données enregistrées sont des éléments chimiques (K_2O, Ba, Ni. B, Au, etc.) ou des minéraux tels que or, tourmaline, ilménite ou silicates de métamorphisme.

Les marqueurs lithologiques montrent une bonne régionalisation permettant immédiatement de séparer les grandes séquences lithologiques : séquence basique, séquence sédimentaire, intrusifs acides ou basiques.

L'or est apparemment lié à plusieurs contextes lithologiques. La zone des indications Or les plus importantes (nombre et intensité) se situe dans la partie Est du secteur (région de Camopi). Un étalonnage sur ce secteur a permis par une interprétation plus poussée de sélectionner une zone à forte potentialité aurifère parmi de nombreux indices.

Les variables K_2O, B, Ba, V, tourmaline se sont révélées pertinentes dans la sélection. Les faits suivants apparaissent :

- identification de deux domaines d'extension décakilométrique à bore élevé ($B > 150$ ppm), orientés selon la direction des structures régionales (N 110°),

- distinction entre ces deux domaines par K_2O inférieur à 1,5 % au Nord et K_2O élevé au Sud (séquence sédimentaire),

- mise en évidence par la répartition de V élevé (> 200 ppm) d'une séquence basique au Nord du domaine à bore seul,

- répartition des fortes concentrations en tourmaline limitée à l'Est du domaine à bore seul, avec débordement sur la séquence basique caractérisant un phénomène hydrothermal.

Des zones à forte activité hydrothermale supposée ont été délimitées au moyen d'une fonction complexe (SIMI) du logiciel SYNERGIE.

Le secteur ainsi sélectionné qui se superpose à des indications aurifères importantes a été retenu pour une exploration en phase tactique.

Quelques utilisations possibles de la géochimie en roches pour la prospection des gisements d'Uranium dans les leucogranites.

P. Leymarie

Une série d'études réalisées dans le cadre d'actions du CNRS, de la Commission des Communautés Européennes et du Commissariat à l'Energie Atomique, ou pour le compte de sociétés minières, ont permis de montrer les possibilités de la prospection géochimique en roches de l'Uranium, ceci à diverses échalles. Nous présentons ici les résultats obtenus dans les massifs leucogranitiques de Valencia de Alcantara (Estramadure, Espagne), Saint Sylvestre et Millevaches (Limousin, France) et enfin Grandrieu (Margeride, France). Les leucogranites constituent vraisemblablement un contexte favorables à l'apparition d'auréoles de diffusion de l'Uranium, du fait de la cataclase qui les affecte.

Pour établir des cartes géochimiques à l'échelle du massif, nous avons utilisé des échantillons en majorité prélevés sur des affleurements. A Grandrieu, des sondages percutants ont permis de combler les vides de l'échantillonnage. Dans tous les massifs étudiés, une maille voisine de 1 échantillon pour km^2 s'est avérée suffisante pour détecter les anomalies liées à des gisements.

A l'échelle de la prospection détaillée, nous disposions de sondages et de prélèvements en galerie, en plus des échantillons prélevés sur affleurements. Une maille voisine de 50 m nous a semblé suffisante pour détecter les halos en roches des formations minéralisées.

Les anomalies de la concentration de l'uranium en roches :

A l'échelle du massif, les principales minéralisations connues se situent dans des anomalies de la concentration en roches de l'uranium, généralement à leur périphérie. L'amplitude des anomalies au dessus du fond géochimique local en surface est d'une dizaine de ppm. Dans le Millevaches, les minéralisations semblent se trouver systématiquement au Nord des anomalies. Cette polarité traduit probablement le sens de migration des solutions porteuses d'uranium.

A l'échelle de la prospection détaillée, les prélèvements en galerie effectués prés du gisement d'Hyverneresse (Millevaches) ont permis de constater une augmentation progressive de la concentration de l'uranium en roches lorsqu'on se rapproche d'une formation minéralisée. Ce halo a une centaine de mètres de largeur et une amplitude maximale voisine de 40 ppm. par rapport au fond géochimique local anormalement bas, de l'ordre de quelques ppm. Des anomalies de quelques mètres le largeur et d'une amplitude voisine de 10 ppm se superposent aux variations régulières de concentration constituant le halo.

Lorsqu'on s'éloigne du gisement, la concentration ne varie plus que dans un intervalle de quelques ppm, autour d'un fond nettement supérieur à celui que l'on observe autour des minéralisations. et les anomalies à l'échelle du mètre disparaissent.

Les observations faites à l'échelle du gisement semblent traduire une remobilisation en système fermé. Cette dernière ne constitue pas obligatoirement le stade terminal du processus de concentration de l'uranium. L'emboîtement d'anomalies appartenant à diverses échelles traduits d'ailleurs vraisemblablement l'existence de plusieurs stades de concentration successifs.

Autres critères faisant intervenir la composition des roches et utilisables pour la prospection de l'uranium :

A l'échelle du massif :

Dans le Millevaches, les minéralisations se situent à la limite des granites sains du centre du massif et d'une vaste zone cataclasée qui apparaît à sa bordure, au contact d'un accident majeur. L'extension et l'intensité de la cataclase ont été cartographiées d'après l'observation en lames minces des échantillons géochimiques. Les concentrations en éléments mobiles sont étroitement corrélées à l'intensité de la cataclase : stables au centre du massif, elles se mettent à diminuer progressivement lorsqu'on s'approche de la bordure du massif, dès que les effets de la cataclase se font sentir.

Les cartes des concentrations en éléments mobiles font également apparaître de grands accidents perpendiculaires à la bordure du massif, qui semblent contrôler la position des minéralisations connues.

Des observations comparables peuvent être faites dans le massif de Grandrieu. Dans le cas où elles ne traduiraient pas directement l'influence de la perméabilité du milieu sur la localisation des minéralisations, on peut au moins supposer qu'elles reflètent les accidents affectant le contact des leucogranites avec les roches encaissantes.

D'autres indicateurs géochimiques, comme le degré d'oxydation du fer, le rapport K/Rb et la présence de zones albitisées, semblent également pouvoir signaler la proximité de minéralisations.

A l'échelle du gisement :

Dans les districts de Margnac et de Fanay (Nord Limousin), ainsi qu'à Hyverneresse, la proximité des épisyénites qui constituent souvent le support des minéralisations est signalée dans les granites encaissants par une augmentation de leur teneur en eau et en silice. On constate le même phénomène au voisinage des syénites de l'Ecarpière (Vendée, France). Le halo enrichi en silice contient peut-être une partie au moins de la silice évacuée par l'épisyénitisation. La présence d'épisyénites peut être détectée de cette manière jusqu'à une distance de 50 à 100 m.

Contribution pour l'étude statistique et structurale de données géochimiques de la région de Coroada (Moura-Portugal).

F.G. Muge
A.J. Sousa
M. Vairinho
V. Oliveira

Ce travail a pour objectif principal de présenter les résultats d'application de méthodes géostatistiques au traitement de données géochimiques issues de campagnes de prospection à échelle régionale et locale.

Les données utilisées tout au long de cette étude sont celles de l'inventaire national des ressources réalisé par le S.F.M. (Serviço de Fomento Mineiro). Il s'agit, dans une première phase, d'une campagne de prospection à échelle régionale dans la région de Coroada (province de l'Alentejo - Portugal).

Dans une deuxième phase de prospection locale ou tactique, la zone sélectionnée a été l'anticlinal de Carrasca-Preguiça.

Les variables disponibles pour l'étude ont été les teneurs en cuivre et zinc des échantillons sols, qui sont suffisantes, dans cette zone, pour montrer les possibilités des modèles géostatistiques appliqués aux données géochimiques. Nous attendons cependant des résultats les plus intéressants de l'analyse pratique multiélémentaire qui est en cours de réalisation.

Les méthodes géostatistiques utilisées ont été la cartographie par krigeage des données géochimiques et la technique d'analyse de données régionalisées par analyse krigeante.

Chacune de ces méthodes repose sur un outil structural de nature probabiliste : le variogramme. La différence principale entre les deux méthodes demeure surtout dans le "poids" qu'on donne à la modélisation des variogrammes.

Dans le krigeage ce qu'on exige du modèle structural c'est de bien représenter les caractéristiques moyennes de variabilité spatiale de(s) variables(s) dans la zone d'étude, tout en assurant la robustesse de l'estimateur de krigeage. Dans cette méthode, l'interprétation géochimique intervient surtout après la cartographie des valeurs.

En ce qui concerne l'analyse krigeante, l'interprétation géochimique doit accompagner l'analyse structurale des variogrammes pour établir un lien entre les concepts d'anomalie et de fond géochimique régional ou local et les structures observées sur le variogramme. Ainsi l'anomalie est normalement liée à la composante aléatoire ou de variabilité à petite échelle et le fond géochimique à la composante structurée à l'échelle régionale ou locale.

Suite à la modélisation structurale des régionalisations, l'analyse krigeante fournit une estimation par cokrigeage des composantes issues de l'analyse structurale aux noeuds d'une grille pour la cartographie ou aux points expérimentaux pour la décomposition des valeurs observées en parties anomaliques et régionales.

Dans son ensemble ce travail a permis de retirer des conclusions géochimiques qui sont en accord avec la connaissance géologique de la région et a aussi conduit à la détection de plusieurs types d'anomalies.

Ainsi, en faisant la comparaison entre les cartographies obtenues et la cartographie géologique, on a vérifié une bonne définition par le zinc des structures et lithologies présentes (avec des fonds proches de 1000 ppm pour les dolomies cambriennes de l'anticlinal de Preguiça) et l'existence de quelques anomalies importantes correspondant à des possibles niveaux minéralisés dans ces formations.

On souligne les zones anomales dans le flanc normal de l'anticlinal, avec les valeurs les plus élevées de la campagne de prospection tactique. Dans ce flanc l'existence très probable d'une faille a été signalée par l'interruption brusque de la bande "anomale".

Dans le flanc inverse, la zone anomale plus importante se situe dans l'extrême NW, tout en suggérant l'existence d'une faille de direction N-S.

En ce qui concerne le cuivre, l'alignement des zones anomales correspond à un "gossan" associé à des volcanites de la base du Cambrien qui occupent l'axe de la structure anticlinale.

En conclusion, il semble que dans ce cas les méthodes géostatistiques, en incorporant la connaissance de l'organisation spatiale des teneurs dans le tracé des courbes d'isovaleurs, ont permis une bonne définition de la cartographie tout en facilitant son interprétation géochimique.

L'analyse géostatistique des données de prospection géochimique.

L. Sandjivy

S'agissant de données régionalisées, c'est-à-dire bien localisées dans l'espace physique, les résultats de prospection géochimique sont susceptibles d'une analyse géostatistique.

Cependant, les techniques géostatistiques développées jusqu'à présent concernent principalement l'estimation des ressources naturelles et la simulation des gisements avec des prolongements en cartographie automatique.

Le problème de l'interprétation des données et son application à la recherche d'anomalies géochimiques a nécessité une formalisation originale et le développement d'outils nouveaux qui sont connus aujourd'hui sous le nom d'analyse krigeante des données.

Pour comprendre l'approche géostatistique de l'analyse des données, il faut rappeler tout d'abord l'existence bien réelle de structures locales et régionales dans la répartition spatiale des données géochimiques. Ces structures sont visibles sur les variogrammes expérimentaux calculés sur l'ensemble du champs de prospection à l'aide d'un nombre important de données généralement, comme l'ont montré les travaux menés successivement au Centre de Géostatistique de Fontainebleau par A. Croissant, S. Suslick, L. Sandjivy, H. Wackernager et G. Girardi.

Mieux, ces régionalisations présentent un certain nombre de caractères communs qui reflètent bien entendu l'environnement géologique et morphologique de la prospection :

- Stationnarité des structures à l'échelle stratégique.
- Présence occasionnelle de dérives principalement à l'échelle tactique.
- Anisotropies liées aux directions géologiques.
- Effet de pépite important.
- Stabilité des portées des structures locales et régionales observée sur plusieurs éléments chimiques dans la même zone de prospection.

L'unicité du phénomène géochimique, traduit par les analyses chimiques mono or multiélémentaires, explique qu'il soit possible, en général, de proposer une modélisation simple des variogrammes à l'aide d'un faible nombre de modèles (2 ou 3) dans les cas mono et multivariables.

Les structures identifiées acquièrent ainsi une certaine objectivité physique que l'on exprime par la formulation suivante :

- L'effet de pépite et les structures de faible portée correspondent au caratère erratique et imprévisible des régionalisation et donc aux anomalies potentielles.

- Les structures de plus grandes portées reflètent l'environnement régional et donc le fond géochimique.

Cette interprétation devient opérationnelle à l'aide des modèles d'analyses krigeante qui permettent d'estimer et donc de quantifier l'importance de ces diverses structures (caractère anomalique ou régional) au sein de chaque échantillon ou du terrain dans son ensemble.

Cette décomposition des analyses mono ou multivariables aboutit à des résultats originaux pour le repérage des anomalies qui corroborent bien dans leurs grandes lignes les conclusions déjà connues sur les zones de prospection sélectionnées pour les cas d'étude mais qui peuvent s'en éloigner de manière significative lorsqu'il s'agit de repérer des anomalies de faible amplitude.

L'avantage des modèles d'analyse krigeante réside dans leur cohérence théorique tout d'abord puisqu'ils intègrent à la fois et simultanément variabilités spatiales et statistiques des données expériementales, mais aussi dans leur simplicité d'utilisation qui en fait un outil opérationnel et performant pour le prospecteur.

L'article propose avant tout des illustrations concrètes de la démarche qui précède en insistant sur les différents types de régionalisation géochimique et les applications de la variographie pour la cartographie automatique et le repérage d'anomalies.

La théorie occupe une place succincte (on décrit cependant les modèles d'analyse krigeante multivariables) pour laisser la place à une première synthèse des possibilités de la géostatistique dans l'interprétation des données de prospection géochimique.

Comparison of probability plots and the gap statistic in the selection of thresholds for exploration geochemistry data.

C.R. Stanley
J. Sinclair

Exploration geochemistry data are commonly treated statistically for the purpose of selecting thresholds with which to define anomalous samples. While most literature in this area has focused largely on case histories which demonstrate the success of various techniques in selecting geologically significant thresholds, little effort has been made to contrast the relative merits and required assumptions of these different methods or to evaluate their efficiencies and sensitivities under various distributional conditions.

In many threshold selection techniques, a comparison is made between the actual geochemical data distribution and a (presumed to be applicable) theoretical distribution model. Deviations in the geochemical distribution with respect to the distribution model lead to the assignment of thresholds and the definition of anomalous samples. While most threshold selection techniques involve a normal distribution model, the assumptions required in the application of each technique may be significantly different. Furthermore, the degree of objectivity/subjectivity of these techniques can vary widely. For this reason, a classification system for threshold selection techniques is proposed which includes 1) Experiential, 2) Model Based-Subjective, and 3) Model-Based-objective categories.

Experiential methods are by definition subjective and commonly take the form of "it must be greater than XYZ to be anomalous". No distribution model is considered and the basis for selection of the threshold is purely past experience.

Model-based-subjective methods involve a theoretical data distribution (usually normal) as well as some degree of subjectivity. Techniques of this type include the "mean plus QRS standard deviations" method, where the subjective selection of the number of standard deviations defines the probability that a sample at that concentration is anomalous.

Model-based-objective methods also involve a theoretical data distribution ; however, threshold selection is objective in that the geochemical data distribution, itself, defines the threshold. Techniques of this type include the gap statistic, and probability plots.

From a scientific standpoint, the model-based-objective methods have the most validity, both because of their objectivity, and their relation to theory. Ironically, they cannot be considered as truly objective because the definition of a theoretical data distribution model is inherently subjective. However, the better the model matches actual data, the more reliable, sensitive, and informative the model-based-techniques will be. Unfortunately, the more assumptions required for a distribution model to describe the complexities of real data, the more constraints on the use of the model. For these reasons, and because of their contrasting levels of model sophistication, the gap statistic and probability plots were evaluated using a Monte Carlo simulation.

Briefly, the gap statistic involves comparing the normal distribution with the geochemical data distribution (which has been monotonically converted to a zero-skewness standardized (Z-score) distribution by a 3-parameter logarithmic transform). The significance level of the largest gap between successive values (analogous to anti-modes on a histogram), relative to what might be expected from a normal distribution, is then compared with critical valuetables to determine its level of significance as a bona fide threshold. The formulation of this technique involves a null hypothesis testing the probability of the standardized geochemical distribution being non-normal.

Conversely, probability plots involve an approach where a multi-modal normal distribution is optimally "fitted" (using a maximum likelihood function) to the geochemical data. Thresholds can be chosen which minimize the theoretical number of classification errors, thus discriminating between the component populations. This distribution model is much more specific (and thus more subjective) than the distribution model of the gap statistic ; however, the probability plot approach allows the additional determination of the central moments of the component populations.

These two threshold selection techniques were compared using randomly generated data sets with a variety of structural variations meant to encompass the variations which might be encountered in actual geochemical data. All 150 data sets generated were bimodally normal and samples were coded as to which mode they belonged. Variations in the number of samples (100...1500), the proportions of the individual components (50:50...95:5), the magnitude of the differences between the means (5...30), and the magnitude of the differences between the standard deviations (5...15) were each represented. These data sets were evaluated using both the gap statistic and probability plots to determine the average number of classification errors (both Type 1 and Type 2) which resulted for each technique under these various data structures.

Results demonstrate that both techniques perform well under most of the data structure variations. In general, probability plots provide marginally better results than the gap statistic. However, for data sets with highly skewed distributions (either because of vastly different component proportions or vastly different standard deviations), the gap statistic demonstrates both extremely high sensitivity and very poor efficiency in correctly classifying individual samples, whereas probability plots perform at a consistently superior level.

These results can be used to determine the expected performance of the gap statistic and probability plot techniques, and their corresponding biases, under various data structure conditions. They also serve to demonstrate the important effects which various distributional assumptions can have on threshold selection.

The results do not "prove" the superiority of one technique over another because each involves its own slightly different set of underlying assumptions related to a theoretical probability density function for the data set being investigated. In application, while the gap statistic offers computational advantage because it can be programmed to determine thresholds automatically, it does not necessarily determine how many populations might be present. As a result, the authors favor the use of probability plots in threshold selection because the method allows for interpretive flexibility and can be adapted individually to fit each data set.

Deux méthodes géostatistiques pour l'interprétation et la détection d'anomalies géochimiques.

H. Wackernagel
C. Butenuth

L'analyse géostatistique de données est fondée sur une décomposition de la structure de données régionalisées en catégories spatiales de variation et en facteurs multivariables.

La structure spatiale de données géochimiques peut généralement être subdivisée en trois catégories de variation : un signal ponctuel (perçu comme bruit), un signal local et un signal régional. L'anomalie géochimique, comprise en tant qu'indicateur de gisement, est associée à l'une ou à l'autre des deux premières catégories spatiales, suivant qu'un amas se manifeste par une anomalie ponctuelle ou une auréole de dispersion géochimique d'une certaine taille. Le variogramme expérimental permet en général de reconnaître plusieurs catégories spatiales à l'échelle d'observation déterminée par la maille d'échantillonnage et cette interprétation est formalisée par le modèle de variogramme.

La représentation de la structure multivariable pour chaque catégorie spatiale est effectuée au moyen de facteurs linéairement non corrélés déterminés par une analyse en composantes principales. La corrélation des échantillons avec les facteurs des différentes catégories est ensuite estimée par cokrigeage.

La deuxième méthode présentée est une application du formalisme de l'analyse discriminante au modèle géostatistique multivariable dans le but d'optimiser la séparation entre le signal ponctuel et le reste du signal géochimique. Cette analyse discriminante spatiale peut être rapprochée de travaux de P. Switzer en analyse d'images, dont elle se distingue néanmoins par l'intervention du modèle de variogramme représentant l'interprétation que l'on donne à la structure spatiale des données.

L'analyse géostatistique de données géochimiques est illustrée par deux exemples provenant respectivement de campagnes de prospection du BGR dans le Rheinische Schiefergebirge (R.F.A.) et du BGR associé à la PREUSSAG dans le Nord-Ouest du Harz (R.F.A.).

Le premier exemple (trois variables, 2049 échantillons de type sol) montre un cas où l'on peut définir sans ambiguité trois catégories spatiales pour lesquelles les corrélations entre les variables s'avèrent très différentes d'une catégorie à l'autre.

Le deuxième exemple (320 échantillons roche) est constitué de seize variables liées par un remarquable effet Guttman. Il semblerait que cette structure des variables peut être mise en rapport avec l'échauffement provoqué par l'émergence d'un corps plutonique à l'époque triassique en bordure de la région échantillonnée. La présence de l'effet Guttman au niveau des deux catégories spatiales que l'on a pu établir pour ces données semble étayer l'hypothèse d'une phénomène régional.

Thème 9 : GEOCHIMIE EN ROCHES
Topic 9 : ROCK GEOCHEMISTRY

The applications of enlarged primary haloes by heavy mineral concentrations of trace elements.

J.J. Barakso

The enlargement of primary halos by concentrating the trace elements utilizing heavy mineral concentration technique is a new tool for rock geochemistry to apply it in geochemical explorations.

This paper describes in some detail the followings :

a) A model of applicability of this technique ;

b) The sampling procedures and applications in some detail ;

c) Three case histories from British Columbia are in considerable detail utilizing this technique, in combination with other existing rock geochemical methods.

The collected samples were analysed for more than sixty elements and the most useful ones of these are discussed for this application.

This technique is designed ultimately to aid the exploration for blind volcanogenic massive sulphide deposits in the three-dimensional perspective, but can be utilized in other metallic search as well.

Evolution of the Catalonian coastal Ranges from Caradocian to Silurian : Interaction between metallogenic processes and physico-chemical environment.

J.M. Carmona
M. Viladevall

The Paleozoic basement of the Catalonian Coastal Range encloses several type of mineralisation for base metals and other commodities. These concentrations have occasionally been exploited, but always at a small scale.

In this area, geochemical studies by the Geological and Geophysical Prospecting Department of the Faculty of Geology (University of Barcelona) have shown anomalous high background values for several elements. This led to the idea of developing a new methodological approach, with a twofold objective : identify, at a regional scale, the metallogenic processes responsible for the high geochemical backgrounds, and define and delineate the corresponding metallotects.

The proposed methodology is based on a regional lithogeochemistry, with selective sampling of shales. Indeed, these rocks may be considered as integrating and reflecting, much better than any other lithofacies, the physical and chemical processes having affected a given sedimentary basin, during and after sedimentation.

Some of these processes are mainly of physical type, with a distal or proximal origin, such as detrital sedimentation from the continent or deposition of fine-grained volcanic materials of continental or basin origin.

Other processes are both physical and chemical, and of distal or proximal origin, generating colloidal substances or solutions from the continent or from hydrothermal or exhalative sources in the basin. In these two cases, interaction with lutaceous materials preexisting in the basin, as adsorption phenomena or ionic interchange, is clear and may persist over long periods.

Every physical or chemical process that was active during the deposition of lutite contributed to some extent to its geochemical composition. The determination of the different contributions to the overall geochemical signature allows the identification of the various contributing processes.

As for the methodology, sampling of shales is along stratigraphic sections evenly distributed in the survey area. Simultaneously, geological data necessary for a proper interpretation of the geochemical results is collected. The samples are grouped into populations corresponding to similar ages. The analytical determinations concern major, minor and trace elements (P, Zn, Pb, Cu, Ni, Mo, Ga, Nb, Zr, Y, Sr, Rb, Th and V).

The analytical data is processed separately for the different populations. Three types of treatments are used :

- numerical treatments : calculation of the Mineralisation Index (Carmona, 1986), based on the Minor Element Enrichment Index (Vine and Tourtelot, 1970) ;
- diagrammatic studies : mainly with modular diagrams (Yudovitch et al., 1984) especially designed for the identification of volcanic or exhalative materials in lutaceous or shale facies ;
- statistical analysis : principal component analysis (PCA) for identifying elements genetically associated with a given physico-chemical process.

The combination of numerical, diagrammatic and PCA approaches allows to determine the morphology and structure of the sedimentary basin, as well as the geographical extension of the generated metallotects in every studied period.

The samples that. do not show any acidic pyroclastic component in the modular diagrams, present high scores for the factor representing the detrital influence, indicating a near continent location. This is often confirmed by geological observations, such as distribution of facies and thickness.

On the other hand. some samples, especially of Caradocian age, show, according to the same modular diagrams, a subtle pyroclastic-acidic component together with high scores for the factor representing a volcanic composition. Most of the time, acidic volcanoclastic or epiclastic layers may be observed in the direct vicinity of such samples. The corresponding volcanic emission centers show a east-west trend.

Samples showing silicification processes, according to the modular diagrams, also present high scores for the SiO_2-Mo factor, representing an exhalative influence. These samples are in general related to chert beds, trending east-west and associated with Ordovician or Silurian black shales.

In the modular diagrams, samples showing the existence of exhalative processes, present high scores for the factor associating base metals, Fe, organic matter and loss on ignition. Such an association very likely corresponds to a coprecipitation of metals with Fe-Mn products. These samples were always collected in black shale layers, in close relationship with chert and pyrite beds.

Similar syngenetic and epigenetic processes may be considered as responsible for the primary enrichment in copper and other base metals, in the Ashgillian and Siluro-Devonian carbonates. Subsequently regional and contact metamorphism generated to the formation of skarn type deposits.

Procedure for evaluation of lithochemical anomalies in large scale mineral exploration.

E.K. Burenkov
G.N. Mukhitdinov
J.N. Reznikov

The objective of geochemical exploration is the detection of anomalous concentrations of ore elements and evaluation ot their ore potential. Methods for detection and evaluation of geochemical anomalies in hydrothermal deposits prospecting are rather well developed now. Recent successes in development of geochemical exploration methods for blind and weakly eroded hydrothermal mineralization deserves special consideration. They are based on characteristic features of composition and arrangement of primary geochemical halos. According to their sizes, primary haloes are much larger than orebodies proper and thus their application for anomalies evaluation increases informative radius of boreholes as many times as primary haloes exceed the proper ore occurrences.

The special features of indicator elements distribution in primary halos identified in numerous ore deposits allow to evaluate a type of hydrothermal mineralization, degree of its erosion and mineralization scale, i.e. they help to differentiate zones of dispersed mineralization and ore accumulations with commercial concentration of useful components, and to reveal areas of maximum reserves of usefull components among the latter. The problem of geochemical anomalies enhancing becomes especially important in search for hidden mineralization. It is attained by construction of multiplicative haloes for possible greater number of indicator elements, according to the analyses of common geochemical samples, their heavy fractions and monomineral concentrates of major ore minerals from halo space.

Cartographic reflection of geochemical information is the basis for prognostic mapping. Areas of ore-bearing anomalies in hydrothermal deposits of various economic types reach tens of square kilometres and are reliably detected on maps of 1/50 000 scale and more. Potentiality of anomalies is defined by the measure of adequacy of geochemical parameters in the compared and standard units.

Wide and successful application of geochemical methods in exploration of hydrothermal (in a wide sense of the word) deposits, became the basis for methodical works for revealing possibilities of their application in the search for sedimentary deposits. This problem is considered below for phosphorite deposits.

Strong and clear regularities were defined in distribution of microelements in rocks of the investigated phosphorite deposits. E.g. in Egorievsk deposit Quaternary depositions are characterized by increased Zr content. Valazhinsk deposits - by that of Zn and Nb, rocks of productive Rjazanskii and Volzhskii horizons by V, Cr, Sr, B and Ge, and, at last, the Oxford clays, underlying productive horizons are enriched by Be, B, Co, Mo, Ni, Rb, Sc, Ti.

The studies of the Koksu, Geres, Kockjohn (Karatau basin) deposits revealed complex geochemical anomalies of manganese, titanium, copper, strontium nickel, vanadium and lead at the contact with productive levels in the overlying dolomites of the Shabaktisk series. These elements produce complex geochemical anomalies in the 200-300 m zone over orebodies. The anomalies are rather stable along strike of the orebodies. They result from development in overlying dolomites of "trains" of high concentrations of indicator elements for phosphorite mineralization which can be applied for exploration of hidden phosphorite bodies.

A number of complex geochemical anomalies, typical for hidden mineralization, were detected during development - production works in promising areas within the phosphorite basis of Southern Kazakhstan. Their exploration revealed phosphorite horizons at the depth of 150-600 m.

The available data on geochemica features of phosphorites allow to conclude that geochemical methods can be successfully and efficiently applied in search for not only phosphorite deposits but for other mineral deposits of sedimentary origin as well.

Geochemical charater of the hydrothermal alteration zones around the Madenköysiirt massive sulfide deposit and its implications for geochemical exploration.

A. Erler

Modenköy-Siirt region lies in southeastern Anatolia, to the northeast of Siirt. The area of study is within the southeastern Anatolian Thrust Belt which forms the boundary between the Border Folds on the northern edge of the Arabian plate and the Taurids. In the region, limestones of the Midyat Group of Eocene-Miocene age, and marl-sandstone alternation of the Lice Formation of Lower-Middle Miocene age are the autochtonous units. Three thrust slices were emplaced over the autochtonous units during Miocene. The lowest slice consists of sandstone-mudstone-marl-limestone-conglomerate alternation of the Sason flysch, Modenköy spilite, and Toptepe conglomerate, all of Eocene age ; the overlying slice consists of Guleman ultramafics of Cretaceous age ; and the uppermost slice consists of Paleozoic Bitlis metamorphics

A wide alteration area around a massive, thin, discontinuous ore zone, is observed within the Modenköy spilite, to the southwest of Modenköy. Within the alteration area, spilites are extensively chloritized : argillic alteration is in the vicinity of the ore zone ; sericitic alteration is together with the ore zone and silicification is below. In Modenköy, the presence of a wide massive mineralized lens of massive pyrite at top and massive magnetite below, has been proved by M.T.A. by drilling. The deposit contains 24.2 million tons of ore with an areverage grade of 1.55 % Cu, and at present is being developed for underground mining. Pyrite-rich zones contain chalcopyrite and very little magnetite ; magnetite-rich zones contain chlorite, little pyrite and chalcopyrite, and very little siderite. The spilites are chloritized and argillized above the massive sulfide lens, and chloritized below. Altered spilites contain pyrite disseminations and veinlets in varying amounts.

Rock samples were collected at surface within the Madenköy spilite around the alteration zone, and also within that zone. In addition, cores of 21 drill holes were examined, logged, and sampled. All samples were analyzed for major oxides, copper, and sulfur.

In relation to the surface alteration zone, the average analyses of spilites, chloritized spilites above the argillic zone, argillized spilites, sericitized spilites within the ore zone, silicified spilites, and chloritized spilites below them are shown on Table 1.

Table 1 - Average analyses of samples from the Surface Alteration Zone

Type	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	H_2O	Cu	FeS_2
Spilite	53.43	15.37	8.17	3.70	7.64	4.13	0.68	4.77	226	-
Chloritic-above	50.81	16.26	11.79	3.79	4.86	3.88	0.71	5.16	627	-
Argillic	55.89	16.71	6.73	2.15	1.39	1.99	2.03	7.62	716	2.74
Sericitic-within	57.41	17.00	-	1.69	0.65	2.69	3.14	7.38	300	7.33
Silicif.	60.55	7.93	16.37	2.02	0.94	3.23	0.52	3.86	620	2.34
Chloritic-below	43.60	14.65	17.87	5.51	4.25	3.34	0.93	5.59	767	1.37

Chloritized spilites within the surface alteration area were depleted in SiO_2, CaO and Na_2O, and enriched in Fe_2O_3, MgO, H_2O, Cu and FeS_2 with respect to the unaltered spilites. Argillized spilites are enriched in SiO_2, Al_2O_3, K_2O, H_2O, Cu and FeS_2, and depleted in Fe_2O_3, MgO, CaO, and Na_2O. Silicified spilites are enriched in SiO_2, Fe_2O_3, Cu, and FeS_2, and depleted in Al_2O , MgO, CaO, Na_2O, K_2O, and H_2O. Sericitized spilites are enriched in SiO_2,^{3}Al_2O_3, K_2O, H_2O, and FeS_2, and depleted in Fe_2O_3, MgO, CaO, and Na_2O ; all iron is present as pyrite. The contents in SiO_2 decrease towards the ore zone, start increasing within the ore zone, and reach its peak in the silicified zone, then decrease again. In contrast, Al_2O_3, Fe_2O_3, K_2O, H_2O, and Cu contents increase. MgO, CaO, and Na_2O contents progressively decrease as the ore zone is approached, and start increasing below the silicified zone. The content in FeS_2 increases towards the ore zone, and decrease below it.

In relation with the massive sulfide lens, the average analyses of spilites, chloritized spilites above the argillic zone, argillized spilites, chloritized spilites within the ore zone, and chloritized spilites below the ore zone are shown on Table 2.

Table 2 - Average analyses of samples from the Drill Holes

Type	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	H_2O	Cu	FeS_2
Spilite	51.17	15.86	7.21	3.94	7.91	4.09	0.97	7.31	142	-
Chloritic-above	42.89	16.13	12.01	6.58	4.92	2.58	0.89	8.10	958	4.30
Argillic-	40.57	16.25	11.93	6.17	1.97	1.77	0.90	10.20	313	9.10
Chloritic-within	29.26	14.43	25.60	13.41	1.20	0.13	0.08	8.07	1523	6.42
Chloritic-below	38.77	15.32	21.57	9.14	1.74	1.71	0.61	6.76	689	3.61
Spilite	51.21	13.45	7.65	4.63	10.30	4.33	0.59	7.74	-	-

Chloritized spilites related to the massive sulfide lens were depleted in SiO_2, CaO, and Na_2O, and enriched in Fe_2O_3, MgO, Cu, and FeS_2 with respect to the unaltered spilites. Argillized spilites are enriched in Fe_2O_3, MgO, H_2O, Cu, and FeS_2, and depleted in SiO_2, CaO, and Na_2O. The contents in SiO_2, CaO, Na_2O, and K_2O progressively decrease as the massive sulfide lens is approached, and start increasing below the massive sulfide lens. In contrast, Fe_2O_3, MgO, H_2O, Cu, and FeS_2 contents increase towards the lens, and decrease below the lens.

The geochemical character of the alteration zones may help in both regional exploration and detailed exploration stages for similar deposits. During regional exploration, rock geochemical surveys may delineate areas of even faint alteration, which may lead to underlying, but non-outcropping ore zones. During detailed exploration, systematic sampling and analysis of core samples for pathfinders such as MgO, CaO, Na_2O, and Cu may help in guiding the drilling program.

On prospecting of porphyry copper mineralization in intra-continental mobile zones (Mongol - Okhotsk - belt, M.P.R.)

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Within the last 20 years one of the biggest porphyry copper deposits in Asia, Erdenetuin-Obo (North Mongolia) was explored and its mining was commenced. This discovery arouse particular interest of geologists for porphyry copper prospecting in Mongolia. New northern Mongolian Province, as compared with majority of world porphyry ones localized in the active margins of lithosphere plates, is situated within the typical intracontinental mobile zone (Mongol-Okhotsk).

The regional geochemical study of magmatic rocks in the zone recognized: (i) structural-magmatic zonation of magmatic areas which is conform with the endogenic ore mineralisation distribution ; (ii) early Mesozoic age of porphyry copper mineralisation in North Mongolia ; (iii) the relation of porphyry intrusion with trachyandesite volcanism in the zone rimming the Dauria-Khentay uplift. As the result the terrains of possible distribution of porphyry ore mineralisation were outlined for the Early Mesozoic stage of magmatism and the prognosis was done for prospecting of such type of mineralisation in Central Mongolia.

The first porphyry copper field was discovered from analysis of the general paleomagmatic setting, considering porphyry dikes and small intrusions of high alkalinity and known evidence of tourmalinization and weak Cu and Au mineralisation of lode type. The comprehensive works, that were nearly simultaneously done, involved : the electrical prospecting by the induced polarization and vertical electrical resistivity sounding methods, pilot petrographic-geochemical mapping with samples and thin sections of bed and eluvial rocks on a relatively even grid ($\sim$250-300 m, 553 samples), geological mapping (1/10 000), soil geochemistry (sampling 250 x 25 m), magnetic prospecting (air and ground), some trenching and drilling were done almost simultaneously.

The petrographic-geochemical and geological mapping ascertained magmatic associations combination which is typical for porphyry copper objects of the region. It included : late Paleozoic granodiorite-granite association, early Mesozoic trachyandesite and porphyry (subalkali diorite, granodiorite, granite, dacite and rhyolite porphyries) associations. The latter two form complex volcano-plutonic systems of stratovolcano type.

The ensemble of hydrothermal-metasomatic rocks consists of propilites (epidote-chlorite and epidote-actinolite facies) ; biotite-quartz-albitic metasomatites : quartz-sericitic and quartz-tourmaline metasomatites, brecciated and banded quartz-tourmaline lodes and zone : argillic metasomatites (clay and hydromica facies). The ore mineralisation types are predominantly pyritic (up to 10-15 %) mineralisation in argillic quartz-sericitic metasomatites and poor stockwork chalcopyrite-pyrite, molybdenite-chalcopyrite-pyrite and auriferous mineralisation in biotite-quartz-albitic-quartz-sericitic metasomatites suffering quartz-tourmaline alteration.

The results of approximative quantitative bedrock analysis (Mo, Nb, Zr, Sb, Bi, Li, Be, B, Cr, Ni, Co, V, Cu, Pb, Zn, Sn, W, Ag, As) were computed via program of muldimentional geochemical fields analysis with plotting monoelements and geochemical association maps. The positive anomalies with coefficients of contrast (C_c) $>$ 5 are ascertained for B, Sn, Mo, Cu, Bi, Zn, Pb, Ag, Sb, As. The most contrast haloes are characteristic of Bi (C_c up to 2000), Ag (C_c up to 400), As and Pb (C_c up to 120). The complex anomalous geochemical field has asymmetric-ring structure with block structure elements, which in general terms coincides with metasomatite zonation. The anomalies of B, Bi and As are of regional type, involving the ore field as a whole (100 km^2). According to the previous estimation, the zoning sequence of pathfinder elements is (Sn, Mo, Cu,)-(Ag, Zn, Pb)-(Bi, As, Sb). It is in general similar to the sequence common for porphyry copper deposit but except for the unusually wide bismuth halo.

The Cu and Mo anomalies have a low contrast. The hypergene processes affect more noticeably the primary anomalies of Cu and Zn, making them weaker. The high contrast multi-element (Ag, Bi, Pb, As) anomalies with high Ag/Bi, Ag/As, Bi/As (blind mineralisation) ratios and accompagnying Cu and Mo haloes are of the most interest for prospecting porphyry ore in the region.

The secondary (soil) haloes are similar to bedrock ones in the element set and structure. But the concentrations of most pathfinder elements are lowered. It was found that As, Bi, Sb, Ag and Pb haloes are as a rule wider (up to 1.5-2 fold) than those in the bedrocks. On the other hand, the Zn, Cu, Mo, Ni, Co anomalies are usually not wider and are often smaller are compared to primary ones. They often seem to be "obliterated" by dilution processes.

Geophysical prospecting by the induced polarization and vertical electrical sounding methods showed large anomaly of complex concentric zonation. coinciding with the area of altered rocks containing sulfides preferably pyrite.

The positive Z anomaly, that is (∿4-5 x 1.5-2 km), elongated north-west along one of the main faults of the ore field (Bajan-Ula) is ascertained by the air and ground magnetic prospecting. It seems to be associated with the uneroded intrusion (quartz-diorites- ?) located at about 0.2-0.4 km depth and having some cupolas on the roof. One of the biggest cupolas is situated in the central part of the main zonal structure, another one in porphyry locality directly adjoining the first in the North.

According to available data, the Bajan-Ula ore-magmatic system is considered as a big weakly eroded complex stratovolcanoe coupled with intrusion. The estimations of formation depth of eroded mineralisation are of order 1.5-2 km. The vertical extent of ore interval is more than 500 m.

Some occurrences with the similar combination of porphyry intrusions, metasomatically altered rocks of geological mapping 1/50 000 at aeromagnetic and geochemical anomalies and positive gamma anomalies in the cases of intensive mainly quartz-alifedspathic and quartz-sericitic alterations.

Thus, prospecting perspectives for porphyry cooper in intracontinental mobile zone of Mongol-Akhotsk type are linked with the terrains of andesite and basaltic volcanism of high alkalinity, binding the internal zones of calc-alkaline magmatism of normal alkalinity.

Application of the zonality of ore associated elements to exploration for volcanogenic massive sulphide deposits : a case study of the Pukkiharjn Zn-Cu prospect, Kuopio, Finland.

R. Lahtinen

Zonality of ore-associated elements

Volcanogenic massive sulphide deposits are characterized by mineralogical alteration associated with distinct geochemical zones, which are larger exploration targets than the observable alteration zones. Use has been made of depletion of Na and Ca and enrichment of Mg, Fe and sometimes of K as a standard procedure in lithogeochemical exploration. The enrichment of ore-associated elements often found in a restricted zone in the area of most intense alteration is also used in locating orebodies, even though their halos are less distinct and well defined than those of major elements. The concept of zonality of ore-associated elements in hydrothermal deposits has been extensively applied in the Soviet Union to interpret the level of erosion and type of deposit and to detect blind mineralization. The direction of movement of the ore-bearing solutions is expressed as axial zonality, and the standard sequence for elements considered here is : Ba-Ag-Pb-Zn-Au-Cu-Ni-Co. In this study, zonality is compared to features of volcanogenic massive sulphide deposits.

In an idealized proximal deposit the movement of ore-bearing solutions near the orebody is through the sub-vertical permeable zone (alteration pipe) up to the sea bottom, where the movement is lateral and possibly controlled by in topography. An orebody deposited on the sea bottom is normally zoned in such a way that the Pb + Zn/Cu ratio increases upwards and towards the margins. The Pb and Ba contents are normally highest in the margins of the orebody, which is often underlain by a Cu-rich stringer mineralization with Zn-rich margins. Gold is often enriched in the Cu or Zn-rich part of the orebody. Silver is incorporated in galena or occurs as sulphosalts in the margins. The behaviour of Co and Ni has not been well established, but the Co/Ni ratio normally increases near the orebody. The lower sulphide-bearing part of the alteration zone has relatively more Co+Ni than the main ore-forming elements (Cu, Zn, Pb). Thus the relative element zonality in a mature, idealized volcanogenic massive sulphide deposit is : Ba-Ag-Pb-Zn-Au-Cu-Co-Ni. This zonality pattern of ore-associated elements is almost the same as the axial zonality proposed by Beus and Grigorian. The only difference is the displacement of Co and Ni ; these elements have, however, low probabilities in their sequence.

The zonality of ore-associated elements in the alteration pipe is not only confined in a vertical direction ; there is also migration of ore-bearing solutions through small fractures and permeable zones. Although these were probably sealed during part of their history, they still show the marks of ore-forming solutions. Sometimes the main alteration zone is surrounded by smaller alteration pipes with different elemental ratios. The application of the zonality pattern of ore-associated elements in the location of orebodies is somewhat hampered by the erratic behaviour of the sulphides and by the fact that the zonality is partly around narrow sulphide veins. Mobilized sulphide veins may also exist in metamorphosed and deformed terrains. The hydrothermal system is probably one that evolves from lower to higher temperature fluids and, in is the waning phase, back to lower temperature fluids again. At the same time the metal ratios may vary. One sampling point or area may thus record only part of the evolutionary path of the hydrothermal system. Despite these problems, the zonality pattern of ore-associated elements is useful in lithogeochemical exploration for volcanogenic massive sulphide deposits, especially in areas where the major element zoning is not well defined. In this case study, the ore-associated element zonality is used to create an exploration model for sulphide deposits in high metamorphic terrains.

Pukkiharju Zn-Cu prospect

The Pukkiharju-Rautalampi volcano-sedimentary association is part of the ca. 1.9 Ga old Savo schist belt. The rocks have been metamorphosed in the granulite facies and subjected to polyphase deformation. The volcanogenic, slightly tholeiitic amphibolites, and Fe, Na and Si-rich acid gneisses form a bimodal suite with geochemical signatures, indicating a tensional island-arc environment. Zinc-rich glacial boulders focused exploration activities on the Pukkiharju area, and two pits containing anomalous contents of Zn, Cu, Ag and

Au were excavated. They were considered the source of ore-boulders, but their geochemical characteristics indicate a more distal and sedimentary environment.

The lithogeochemistry around the pits was studied on samples taken from seven drill holes (Fig. 1b). The mineralized horizon indicating lateral movement of ore-bearing solutions is interpreted as being located near the boundary of volcanic and sedimentary associations. These are separated by the first occurrence of graphite-bearing rocks. Major element data indicate that the rocks are altered to varying degrees. Geochemical interpretation is hampered, however, by the common occurrence of carbonates and calc-silicate minerals. The Mg and K-rich cordierite-sillimanite gneisses with locally very low Na, Ca and Sr contents are considered the metamorphic equivalents of altered acid volcanites.

Disseminated sulphides are abundant in the drill cores studied, and sulphur contents of up to 28 % have been encountered. Pyrrhotite is the prevalent sulphide, but pyrite contents increase near the mineralized horizon. The data on ore-associated elements were smoothed using weighted means for 15-25 m of drill core divided into basic and acid sections. Only the sections containing over 1 % S were considered. The background median values of amphibolites and acid gneisses were subtracted from the Cu, Zn, Ni and Co values. The Pb values were not included, because they are normally below the limit of analytical detection.

The values of ore-associated elements are considered to represent mainly the sulphide phase. Cu/S, Zn/S, Ni/S and Co/S ratios were used to level out the variance in sulphide contents, and the ratios of Co/Ni and Cu+Zn/Ni+Co were used to accentuate the possible zonality patterns. Six geochemical zones were established (Fig. 1a). Zone 1 has low Zn/S and Cu+Zn/Ni+Co ratios, with an increase in Co/Ni and a decrease in Ni/S ratios in the direction indicated by arrows in Figure 1a. Zone 2 surrounding zone 1 has higher Zn/S and Cu+Zn/Ni+Co ratios. Zone 3 is characterized by high Cu/S, Ni/S, Co/S and moderately high Co/Ni ratios. This zone is interpreted as being situated lower in the local stratigraphy. Zone 4 has high Cu/S, Co/Ni and Cu+Zn/Ni+Co ratios and low Ni/S and Co/S ratios. The highest Zn/S and Cu+Zn/Ni+Co ratios are in zone 5. Zone 6 partly overlaps zone 2, but has higher Cu/S, Zn/S and Cu+Zn/Ni+Co ratios. Zones 1-3 are totally devoid of Ag, and the highest Ag values were encountered in zone 5. Gold behaves somewhat erratically, but the highest values were found in zone 5.

The above data were interpreted on the basis of the concept of zonality of ore-associated elements. Zone 1 represents the lower part of an alteration pipe and zone 2 its margins. Pyrrhotite-rich zone 1, in the lower stratigraphic position, surrounded by zone 3, probably represents the centre of an alteration pipe. Zones 4 and 5 represent the margins of the upper part of the alteration pipe, perhaps close to a stringer mineralization. Zone 6 partly coincides with the mineralized horizon. The flow direction of ore-bearing solutions is indicated by arrows in Figure 1a.

The Pukkiharju Zn-Cu-prospect is a volcanogenic massive sulphide-type mineralization in carbonate-rich volcano-sedimentary rocks. The proximal mineralization is probably located under zones 4 and 5 and the ore-boulders indicate the existence of a more distal type of mineralization. A tentative model is presented whereby the sub-vertical alteration zone has been transposed into a position nearly parallel to the schistosity and possibly detached from the orebody.

Thème 10 : PROSPECTION GEOCHIMIQUE REGIONALE
Topic 10 : REGIONAL GEOCHEMICAL EXPLORATION

Inventaire minier transgabonais : Campagnes géochimiques régionales et détaillées 1979-1986. Acquisition des données sur le terrain.

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Depuis 1981, le Gabon a entrepris un vaste programme de travaux de télédétection (radar et géophysique aéroportée) et d'exploration minière de la zone desservie par le Transgabonais. Cette opération est financée par l'Etat avec un appui du FAC (Fonds d'Aide et de Coopération français) et l'aide du FED (Fonds Européen de Développement) pour les travaux aériens. Deux opérateurs sont en action, le Service Géologique National (1979) et le BRGM (1981).

Ce programme consiste à dresser l'inventaire minier d'un vaste territoire, dont la part échue au BRGM et prospectée entre 1981 et 1986 couvre quelques 42 000 km^2 dans les régions de Mitzic, Booué et Mouila. La surface impartie au Service Géologique totalisant 22 000 km^2 comprend les feuilles à 1/200 000 de Kango et Lambaréné.

La zone du projet est située à cheval sur le fleuve Ogooué. Le climat y est du type équatorial, avec un pluviométrie annuelle variant entre 1 500 et 2 000 mm. La forêt primaire, sempervirente, n'est absente que lorsque dégradée par l'activité anthropique. Le relief est moyennement très accusé, avec des altitudes s'échelonnant entre 100 et 800 m. L'altération superficielle. caractérisée par des profils dits "à stone line", est intense et affecte les roches sur une profondeur pouvant atteindre la centaine de mètres.

En ce qui concerne la géologie, on peut distinguer trois unités principales :

- l'Archéen, avec des granitoïdes et des sillons ferrifères ;
- le Protérozoïque inférieur, avec les grès et pélites du Francevillien, et les séries de l'Ogooué, plus métamorphiques, à gneiss, schistes, quartzites et localement roches vertes :
- le bassin sédimentaire comprenant des séries permo-triasiques à éocènes. avec les formations continentales de la Noya, les séries anté et post salifères.

Les principaux objectifs miniers sont l'or dans l'Archéen ou dans le Protérozoïque inférieur métamorphique, et les amas sulfurés polymétalliques dans les mêmes terrains. Les terres rares, associées à certains intrusifs granitiques spécialisés, constituent également un objectif plausible.

En préambule à la prospection régionale, toutes les données disponibles (radar, photogéologie, spectrométrie et magnétisme aéroporté) sont rassemblées et intégrées pour constituer les documents de base sur lesquels s'appuie la prospection au sol, qui comprend :

- une reconnaissance géologique, avec établissement de cartes d'affleurements ;
- une prospection géochimique "stream sediments" ;
- une prospection alluvionnaire.

Les paramètres opératoires de la prospection géochimique sont les suivants :

- échantillonnage des drainages secondaires, à une densité de 2-3 prélèvements/km^2 ;
- séchage et tamisage avec récupération de 2 fractions granulométriques : $<$ 63 microns et $<$ 125 microns ;
- analyse d'un échantillon sur deux (fraction $<$ 63 microns) par spectrométrie plasma (ICP) ; dosage de l'or par absorption atomique, sur échantillons correspondant à des zone sélectionnées (fraction $<$ 125 microns).

De la sorte ont été prélevés, entre 1981 et 1986, 113 680 échantillons de stream-sediments, dont 60 550 analysés par ICP et 7 260 pour Au.

En prospection alluvionnaire, les concentrés sont prélevés, à la batée, à raison de 0,5 à 1 échantillon par km^2. Les échantillons font ensuite l'objet d'une étude minéralogique semi-quantitative.

La mise en oeuvre d'un tel dispositif en forêt équatoriale et avec une infrastructure réduite se heurte à des problèmes logistiques importants. Le support héliporté est indispensable, mais l'exécution du travail est essentiellement à base d'itinérance. Jusqu'à 10 géologues et 30 aides prospecteurs participent aux opérations, qui se déroulent exclusivement en saison sèche (juin à octobre).

En suivant un échéancier très serré, de manière à disposer de l'ensemble des résultats avant le début de la campagne suivante, la phase de terrain est suivie de la compilation et interprétation des données récoltées.

Les données de la prospection géochimique sont traitées en mettant en oeuvre tout l'arsenal des techniques statistiques et cartographiques, avec une double finalité : (1) isoler les anomalies susceptibles de correspondre à des objectifs miniers et (2) fournir un appui à la cartographie géologique, lourdement handicapée par le manque d'affleurements. Les anomalies sont archivées dans un fichier facilitant les consultations et mises à jour ultérieures.

L'ensemble des résultats est rassemblé dans un rapport final édité environ 8 mois après l'achèvement des travaux de terrain.

La phase régionale est suivi d'une phase de contrôle des anomalies les plus significatives, par un enchaînement de 4 étapes permettant d'actualiser le coefficient de priorité des anomalies traitées :

1. resserrement de l'échantillonnage "stream-sediments" et alluvionnaire, respectivement à raison de 6-8 et 2-4 échantillons/km^2.

2. géochimie en sols, à une maille de 200 x 50 m ou 200 x 100 m.

3. vérification des enracinements d'anomalies par travaux de subsurface : tranchées, sondages à la mototarière.

4. reconnaissance des structures minéralisées par sondages profonds.

L'ensemble de la démarche suivie, aux différentes phases de la prospection, s'appuie sur des études méthodologiques visant à optimiser l'adéquation entre les procédures adoptées (échantillonnage, préparation des échantillons), le but poursuivi et les conditions morphopédologiques locales. La complexité des situations altérologiques rencontrées dans les milieux équatoriaux rend en effet indispensable cette synergie de la méthodologie de la prospection géochimique et de son aval opérationnel.

Geochemical mapping in the nordkalott project, northern Fennoscandia.

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The project area covers the northern parts of the Fennoscandian Shield and the Caledonian fold belt north of the 66th parallel in Finland, Norway and Sweden.

Samples of soil, organic material, till, stream-sediment, stream organic matter, stream moss and stream water were collected from 7267 sites within a 250,000 km^2 survey area. Fine and heavy fractions of the mineral samples and ash of the organic samples were analysed by optical emission spectrometry, X-ray fluorescence, and neutron activation methods.

Analytical results for till, stream-sediment, stream organic matter and stream moss are presented on 136 single-element and 6 principal-component maps. An interpretation map was compiled by visual inspection of the geochemical maps. An atlas of these maps together with accompanying geological and geophysical maps is being published at a scale of 1:4,000,000.

The survey area was classified into eighteen geochemical provinces. A northewest running zone of high contents of mafic elements, e.g. Cr, Mg and Ni, marks a greenstone belt in the northeastern part of the area. There is an abrupt geochemical change towards the northeast along the margin of this zone and a trend of decreasing contents of mafic elements and increasing contents of felsic elements from the zone towards the southwest.

Other remarkable features are the existence of several geochemically different areas within the granulite and Middle Lapland granite complexes in Finland, the particular geochemistry of the Barents Sea group in northeastern Norway, and the continuation of the Logoda-Bothnian Bay zone in the project area in Sweden.

Several geochemical anomalies of various sizes and shapes occur, of which some are being followed up. It is concluded that regional multi-media and multi-element geochemical mapping with low sampling density can delineate areas favourable for exploration as well as produce data useful in environmental research.

Review of Sawang-Labuhan Haji geochemical follow-up, northern Sumatra Indonesia.

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The survey area is located on the western flank of Northern Sumatra lying between latitudes 3°18' - 3°33' North, and longitudes 97°7' - 97°12' East.

Physiographically the area is part of the southwestern coastal plain and of the western coastal range. The climate is tropical and the area is covered by primary or secondary forest. The average annual rainfall is 3250 mm. Topographically, the flat coastal plain rises drastically in the northeast of the survey area to about 600 metres with a series of subparallel mountain ranges dominating the area.

The oldest rock type is the Permo-Carboniferous Kluet formation which comprises phyllite, slate, schist and gneiss ; overlying the Kluet Formation is the Tapaktuan Formation of the late Jurassic early Cretaceous age. It consists of metavolcanics and metalimestones and covers most of the area. Tertiary shales of the Loser Formation are exposed in the westernmost part of the area. The intrusive rocks recorded in the area are diorite and granite. The granite is dated 50.9 + 1 My age (Eocene) by the K/Ar method.

Mineralization is found in volcanic floats of the Tapaktuan Formation. However, silicified tuff and agglomerate outcrops of the same formation contain disseminated pyrite. Secondary copper appears in propylitised and epidotised andesite and basalt. Malachite and chalcopyrite associated with magnetite/hematite also occur as fracture filling/veinlets in the volcanics of the Tapaktuan Formation. Previous reports have suggested that the mineralization type is volcanic exhalative and/or hydrothermal with massive sulphides.

In order to detect base metal mineralisation the 1978 follow-up geochemical survey was conducted and 427 stream sediment samples were collected from an area of 385 km^2. The -80 mesh fraction was analysed for 17 elements (Cu, Pb, Zn, Co, Ni, Cr, Li, K, Fe, Mn, As, W, Sn, Mo, V, Ag and Sb), by AAS and visual colorimetric methods.

Twelve elements are presented as a series of single element class interval maps based on the standard deviation parameter. Copper anomalies (105 ppm) in the stream sediment are found in the northern part of the area (i.e, around Labuhan Haji village), however lead and zinc values are generally low.

Anomalies in the area have not yet been checked. Further follow-up is recommended over a smaller area with the collection of other sample types including rocks, soils and panned concentrates.

Geochemical atlas of Finland.

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During 1984-85 the Geological Survey of Finland carried out a regional geochemical mapping of till at a scale of 1:2,000,000, with the purpose of producing the data for the first Geochemical Atlas of Finland. The Atlas is being designed to give as broad as possible background information about the distribution of elements in rocks, soils, and the environment.

The primary data for the Atlas is provided by 1057 composite till samples collected from all over Finland. The mean sampling site density was one /300 km^2. Each composite sample comprised five subsamples, which were collected from an area of 0.5 by 2.5 km^2 (elongated perpendicular to the direction of ice movement). The sampling was mostly done with the aid of light percussion drills and from an average depth of 1.5 m.

The composite samples (ca. 0.5 kg) were dried and sieved to pass a 0.06-mm screen, preparatory to analysis mainly by inductively coupled plasma spectrometry (ICAP) and instrumental neutron activation analysis (ENAA). Other techniques employed were graphite furnace atomic absorption spectrometry (GAAS) for gold and palladium and Leco Determinator for sulphur. For ICAP determinations two sample preparation techniques were used : leaching with aqua regia and dissolution with hydrofluoric and boric acids. The usual precision of the methods is better than 20 % ($P = 95$ %).

The element concentrations are presented as coloured background maps smoothened and gridded to 2 by 2 km cells. The smoothing is based on a weighted moving median within circular windows (radius 100 km). Samples near the centre of the circle are given high weights and peripheral samples low weights. The weighting function is bell-shaped.

The coloured maps are drawn with an ink-jet plotter. Each grid cell is coloured according to the concentration level in the grid. The colour scale corresponds to a logarithmic concentration scale.

Interpretation of the geochemical material is underway at the Survey. Some representative maps are shown and discussed from the point of view of potential users.

Geochemical prospection activity in Austria by the Geological Survey and Voest-Alpine AG.

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1 - The geological survey of the Central Alps and the Bohemian Massif

Sampling : along the natural stream pattern and according to accessibility of the sample site a certain amount of active stream sediment as rich as possible in fine-grained materials was taken : a total of 30,000 samples. Statistically the sample density is 1.4 km^2/sample.

Sample treatment : the samples were air-dried or dried in heated rooms (always below 60°C) of local saw mills and shipped to the laboratory.

Sample preparation : the samples were ovendried below 80°C in the laboratory and sieved. From the minus 80 mesh fraction (below 0.18mm) a small portion was taken for grinding to minus 300 mesh : this represents the analysed material.

Analysis : the bulk of the analysis was done by multi-element methods (ICP and X-ray fluorescence), silver, lead, molybdenum and tin by optical emission spectroscopy, antimony by atomic absorption and arsenic by Gutzeit. Altogether the samples were analyzed for 35 elements.

The raw data are plotted on single element maps (scale 1:50,000) with the respective class symbol on the sample site. The same data will be presented as "The geochemical Atlas of Austria" on the scale 1:1 million smoothed by a moving average method.

The reproducibility of the geochemical survey : within a bigger set of samples a series of standard sample has been submitted to the laboratory to calculate the analytical variance. The total variance was calculated after re-sampling 680 sites. The portion of the variance then due to re-sampling was estimated from the total variance and the analytical variance. For most of the elements the variance of re-sampling after 1 to 3 years, expressed in 1 standard deviation of the respective mean value, was quite below 10 %.

The reproducibility of the geochemical survey is affected by an other factor, the time component over the entire project, despite all endeavours toward standardisation. This is expressed in the fact, that in the univariate or element ratio maps in the scale 1:1,000,000 the survey area is broken up into subunits according to shipments and/or runs of sample preparation. Although unidesireable this affect can be reduced for data evaluation in processing the homogenous areas individually.

2 - Scheelite prospection

Together with the stream sediment a panned concentrate of the sediment fraction below 0.335 mm was taken on the same site for tungsten prospection. After visual analysis by ultraviolet light more samples were taken in positive areas at much closer spacing. While the project is still in the stage of documentation, a number of geologically not explainable zones or isolated high values are evident already in the univariate maps : together with results of the multi-variate data evolution they will be candidates for follow-up considerations. Besides this a great number of hints and questions arise for further geologic research and interpretation. As an example may be mentioned the tectonic position of the Ennstal quartzphyllite. For years it has been discussed wether it belonged to the Upper Austro-Alpine or to the Lower Austro-Alpine nappe unit same as the adjacent Radstatt quartzphyllite. In its chemical composition as expressed in the stream sediments it can easily be differentiated from the latter, but surprisingly it resembles very much the Lower Austro Alpine Innsbruck quartzphyllite as both seem to have been fed from the same hinterland, which could very likely have been the now lacking part of the Middle Austro-Alpine. Another example may be the Rastenberg granite in the Bohemain Massif, with its very particular spectrum of trace and minor elements so different from other similar granites.

So we are looking forward to interesting results, for mineral exploration as well as for geology.

Prospection géochimique dans le centre et le nord-ouest du Burkina Faso.

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F. Ouedraogo

Suite à la découverte en 1981 de l'amas sulfuré Zn-Ag de Perkoa par prospection géochimique régionale dans les bandes birrimiennes de Boromo et de Houndé (Projet PNUD UPV 74/004), un nouveau projet (PNUD-BUMIGEB BKF 83/002) appliquant la même démarche, qui a fait ses preuves, et couvrant le centre et nord-ouest du pays, a été lancé.

La communication présentera les résultats de cette campagne géochimique régionale en sols et abordera les divers problèmes rencontrés ; ceux-ci sont communs à toute prospection dans la zone tropicale sèche d'Afrique occidentale. Sera également décrite la solution adoptée pour le stockage des nombreuses données analytiques (plus de 100 000 échantillons) avec mise en service d'une unité micro-informatique. Cette solution a déjà permis la création d'un fichier contenant les références des échantillons (numéros, coordonnées) et les données analytiques en vue de traitements statistiques divers. L'acquisition récente de logiciels permet actuellement de produire des cartes à partir des données stockées dans le fichier.

Cette organisation ouvre des perspectives nouvelles pour la valorisation des données du sous-sol au Burkina-Faso.

Synthèse géologique et métallogénique du faisceau de Pontgibaud et de ses marges (Massif Central français).

J.L. Marroncle
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J.Cl. Prévost

The "Pontgibaud" vein swarm is a NN-E trending system exploited since Roman time for lead, zinc and silver and located in the heart of the Massif Central about 30 km west of Clermont-Ferrand town.

About 6 500 km^2 surrounding the Pontgibaud vein swarm have been systematically explored by BRGM, as part of the National Inventory of Mineral Resources sponsored since 1975 by the French Government. A synopsis of the results of several years of reconnaissance and follow-up surveys has been attempted by the Massif Central Mining Division geologists, in close cooperation with the technical services of BRGM in Orleans.

A multidisciplinary approach including geological and structural mapping, teledetection, compilation of geophysical and geochemical data has permitted to enlight some of the parameters which control the regional metallogenesis and location of known and inferred mineral resources.

The study area is limited to the east by the tertiary sediments of the "Limagne" graben, to the south-east by the Quaternary volcanics of the "Chaîne des Puys", to the south west by the Ussel and Meymac granites, to the west by the Gueret granite and to the north by metamorphic rocks of the "Sioule" series. The area itself comprises metamorphic rocks of various types and ages intruded by Upper Devonian to post Upper Visean granites (360 to 280 My).

The area is transected by a major NNC trending strike-slip fault ("Sillon Houiller") along which several narrow elongated grabens, filled in by carboniferous coal measures and volcanics, have developed.

Among the results of this synopsis, the following are particularly noticeable :

- Beyond the prominent NNE (Hercynian) vein directions, the existence and metallogenietic significance of another, NW-SE (Armorican) structural trend, already suspected by geologic mapping, is confirmed by teledetection, geophysical and geochemical interpretations. Furthermore, most known occurrences are located at or near the intersections of these two fracture sets, both of which seem to have acted as hydrothermal drains.

- Several circular structures evidenced by teledetections and sometimes correlated with geophysical or geochemical anomalies may suggest the existence of concealed intrusions of possible metallogenic interest.

- In relation to the more recent granitic intrusions, a tin-tungsten and to a lesser degree molybdenum potential, is revealed through geochemical and alluvial prospecting results. Tin resources are otherwise known at both ends of the study area : to the SW (Meymac granite) and to the NE (Echassières deposit).

- The metallogenic history is complex and involves at least two superimposed pulses of mineralization : the second, lower, temperature mineralization (Ba, Pb, Zn, Ag, Sb, F, Cu) may often mask the earlier higher temperature mineralization (Sn, W, Mo, Au).

As a result the study provides guidelines for further exploration through the enlightment of the physical controls of mineralizations (two orthogonal fracture sets + circular structures) and of its relation to differentiated granites. Furthermore a potential appears for other types of mineral associations than the ones previously exploited (Pb, Zn, Ag, Sb), namely Sn, W, Mo and Au.

Le programme décennal d'inventaire des ressources minérales de la France.

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J.J. Périchaud
L. Viallefond

Suite au premier choc pétrolier de 1974 qui révéla la vulnérabilité de la France pour son approvisionnement en matière premières minérales, un important programme décennal d'inventaire de ses ressources minières a été confié par les pouvoirs publics au Bureau de recherches géologiques et minières pour relancer l'activité dans ce domaine. Limitée aux formations protérozoïques et paléozoïques et à leurs bordures sédimentaires, une telle prospection systématique va de la phase régionale aux contrôles tactiques en incluant la reconnaissance des cibles par sondages ; elle a pour objectif de renouveler les sujets susceptibles d'être pris en charge ultérieurement par la profession ; elle fait largement appel, aux techniques géochimiques multiéléments. Bien qu'une telle approche de caractère systématique et assez exhaustif ne paraisse plus adaptée aux réalités d'un marché des matières premières qui s'est considérablement déterioré depuis lors, il s'avère utile de dresser un premier bilan à la fois des méthodes mises en oeuvre et des résultats obtenus. Cette rétrospective se limite au domaine de la seule prospection géochimique.

◊ La prospection stratégique multiéléments :

- Conception

L'accent a été mis sur la mise en évidence d'anomalies signficatives directement liées à une minéralisation et non sur la sélection d'unités géochimiques "potentielles", caractérisées par exemple par une augmentation du fond géochimique pour tel ou tel élément. L'adaptation de la maille d'échantillonnage aux extensions, en général assez restreintes dans nos zones climatiques, des auréoles de dispersion secondaire des métaux , nous a conduit à retenir des densités allant de 2 à 4 éch./km^2, suivant les conditions morphologiques locales. Ce choix tient compte, pour la détection d'objectifs souvent restreints (minéralisations à Sb et W par exemple), des apports liés aux auréoles multiples fournies par l'analyse multiéléments.

- Prélèvements

- Afin d'obtenir une densité de prélèvements relativement homogène, nous avons adapté l'échantillonnage aux conditons morphologiques locales en collectant sur un même prospect différents types de matériaux. Ainsi, les "stream sediments" constituent l'ossature d'une campagne stratégique ; ils peuvent être relayés, soit par des prélèvements de "sols en fond de vallon" dans les zones amont des drainages secondaires où l'alluvionnement fait défaut, soit par des prélèvements de "sols" sur alluvions ou colluvions dans le cas où les alluvions en lit vif sont trop grossières ou font défaut. En outre, dans les régions où des travaux miniers anciens ou actuels sont à l'origine de contaminations importantes des sédiments, nous avons substitué aux "stream sediments" un échantillonnage de sols à maille 500 x 500 m, modulée par la morphologie ; les prises se font en effet dans les fonds de vallon pour profiter des remaniements et colluvionnements liés à la solifluxion.

La combinaison, en reconnaissance régionale, de différents types de prélèvements accroît la variance d'échantillonnage, et s'oppose par là, à la démarche conventionnelle du géochimiste ; elle trouve cependant sa justification au niveau d'une prospection multiéléments qui permet de minimiser les critères purement statistiques lors de l'interprétation des données et de la sélection des anomalies.

- Préparation des échantillons et analyses

Les échantillons ont été homogénéisés par un tamisage à moins 125 µ et analysés par spectrométrie d'émission à plasma conductif.

Cette technique permet le dosage de 22 éléments traces préalablement mis en solution par attaque triacide. La qualité des résultats analytiques fournis est comparable à celle des dosages obtenus par absorption atomique.

L'or n'a pu être pris en compte, par cette méthode : cet élément n'a été dosé, par absorption atomique, que très localement, en prospection régionale.

- Traitement et interprétation des données

L'information multiéléments nous a conduit à ne plus définir une anomalie à partir d'une teneur de coupure choisie statistiquement sur une population globale, mais a tenir compte de son "environnement géochimique", précisé par la répartition des autres éléments traces dosés et en particulier par les associations d'éléments mises en évidence.

Sont ainsi mieux pris en compte les notions de teneurs formationnelles dont la discrimination par rapport aux anomalies d'intérêt métallogénique reste une préoccupation majeure du géochimiste.

L'augmentation considérable du volume de l'information numérique à traiter a naturellement nécessité l'utilisation de l'ordinateur couplé à des moyens de visualisation adaptés aux différentes échelles de travail.

Pour l'analyse numérique des données, nous avons fait appel aux différents programmes maintenant classiques, d'analyse statistique mono-élémentaire, bivariée et multivariable ; parmi ces dernières, les technqiues de regression paraissent les plus performantes pour la recherche et la définition des anomalies car elles permettent souvent, en particulier pour des éléments sensibles aux fluctuations lithologiques, de s'affranchir du fond géochimique et de ne garder que les valeurs "résiduelles". Les techniques de classification hiérarchique des échantillons sont également très performantes pour la définition et la cartographie des unités géochimiques et en particulier de celles précisant l'environnement spécifique des diverses anomalies mises en évidence.

◊ Les contrôles tactiques :

Malgré un diagnostic rendu de plus en plus précis par l'information multivariable et par voie de conséquence une sélection de plus en plus affinée des anomalies stratégiques, toute quantification des teneurs anomales reste aléatoire, le signal géochimique dépendant avant tout de la nature de l'intersection de la minéralisation recherchée avec la surface topographique. Les contrôles à réaliser restent donc nombreux et leur articulation s'appuie en général sur une mise en oeuvre, combinée ou non, de levés géologiques détaillés, de géophysique au sol et de géochimie tactique. Sur le plan géochimique, le nombre des échantillons tactiques nécessaires au tri des anomalies régionales est au minimum, d'après l'expérience acquise, du même ordre de grandeur que celui des prélèvements stratégiques.

Les contrôles se font la plupart du temps en sols à maille régulière (200 x 200 à 50 x 50 ou 50 x 25 m ou même 50 x 10 m), les analyses, initialement mono ou pluri-élémentaires, limitées aux associations d'éléments définissant l'anomalie stratégique, ont tendance à devenir de plus en plus multiélémentaires.

Les recherches d'enracinement des minéralisations ont été conduites par échantillonnage de profils tarière ou tranchées. L'analyse à pas serré de ces matériaux de "bedrock" , couplée aux données géophysiques a, dans la majorité des cas, grandement facilité la focalisation des cibles à sonder.

◊ Quelques chiffres sur les premiers résultats de l'Inventaire géochimique :

L'effort de prospection régionale réalisé porte sur la collecte de 270 000 prélèvements ; le traitement des données analytiques associées a fourni environ un millier d'anomalies significatives inédites, mono ou polymétalliques, abstraction faite des contaminations anthropiques ou dues à d'anciens travaux.

Sur les 400 premiers contrôles tactiques réalisés à ce jour, combinant prospection à vue, prospection alluvionnaire, géophysique et échantillonnages en sols et tarière à maille régulière (environ 40 000 prélèvements), seuls une soixantaine de sujets a été amenée au stade du contrôle par sondages, les autres correspondant à des objectifs à priori trop restreints, soit en extension, soit en teneurs.

◊ Principaux types d'objectifs mis en évidence :

D'une manière très caricaturale , signalons en préambule que les résultats les plus inédits ont été obtenus dans les régions à forte couverture pédologique telles le Massif Armoricain, par comparaison aux régions à sols résiduels plus sporadiques du sud-ouest ou de Corse par exemple, où de nombreux indices avaient déjà été repérés à vue.

Les anomalies les plus spectaculaires par leur extension, leur contraste et souvent par leur signature polymétallique, sont à associer pour l'essentiel à des minéralisations disséminées mais à grand volume. Ce type de cibles à stock métal important mais à faibles teneurs dont l'intérêt économique reste très marginal, est très facilement détecté par l'outil géochimique en fournissant une image s'apparentant à des anomalies formationnelles.

Deux types de présentation ont pu être reconnus, sans que leur discrimination précoce, à l'échelle régionale, ait toujours été possible.

Il s'agit par ordre d'importance :

- de minéralisations de "départ acide" s.l. (Be, W, Sn, As, associés de manière plus sporadique à Bi, Li, Mo ...) exprimées sous forme de stockwerks, greisens, skarns, ... La multiplicité des concentrations nouvelles de wolframite et scheelite mises à jour, et leur importance en ce qui concerne en particulier les skarns à scheelite, conforte la vocation traditionnelle du socle hercynien pour le tungstène ;

- de minéralisations de type "porphyry-copper", à dominante molybdène, dont les différents faciès d'altération hydrothermale ont pu être repérés dès la phase de contrôle tactique en sols. Ce type d'objectif est tout à fait nouveau en France.

Une seconde catégorie d'anomalies reconnues correspond à des minéralisations liées aux strates en domaine sédimentaire de couverture : il s'agit pour l'essentiel de grandes plages anomales à Pb, Ba, Zn, (F), frangeant les formations du socle du nord du Massif Central ou du Massif Armoricain. Leur détection est aisée, même à une maille géochimique lâche, mais leur intérêt métallogénique est faible.

Les anomalies polymétalliques en domaine volcano-sédimentaire soit ancien et métamorphique, soit dévono-dinantien, sont à associer à des minéralisations de type amas sulfurés dont les réponses géochimiques sont en moyenne plus ponctuelles et moins contrastées : si Pb constitue l'élément de la paragenèse primaire le plus robuste dans le domaine superficiel, des teneurs anomales complémentaires en Ag et plus accessoirement Cu et Zn, plus sensibles à l'altération pédologique, peuvent conforter localement un diagnostic gîtologique précoce. Les données géochimiques obtenues ont conduit en particulier à la mise en évidence en Bretagne, de deux nouvelles provinces à amas sulfurés, localisées en bordure du bassin de Châteaulin, et dans la région de St Georges-sur-Loire.

En dernier lieu, de nombreuses anomalies ont permis la mise en évidence de structures filoniennes inédites : minéralisations à Pb-Zn-Ag, filons à tungstène, à antimoine, filons à fluorine et/ou à barytine. Ce sont des objectifs plus difficiles à cerner par approche géochimique, par suite de leur structuration unidimensionnelle ; ils induisent des anomalies faibles, tant en teneur qu'en extension et leur sélection reste souvent hasardeuse, surtout quand elles sont monoélémentaires ; dans ce cas, l'association avec une anomalie "alluvionnaire" devient déterminante pour la sélection de la cible.

La découverte de concentrations antimonifères nouvelles en Bretagne et en Vendée, tout en confirmant, là encore, une vocation ancienne du sous-sol français, a débouché sur une exploitation d'antimoine et sur des projets en cours d'équipement de petites mines.

Ainsi, si la conjoncture particulièrement maussade a considérablement ralenti le développement ou la faisabilité de projets miniers issus de l'inventaire et en particulier des sujets présentés à la profession minière et repris par les compagnies d'exploration pour compléments d'investigation, il n'en demeure pas moins que le portefeuille de prospects, d'indices, voire d'anomalies nouvelles restant à travailler a été fortement enrichi.

De même, les nombreuses données analytiques acquises permettent l'élaboration de synthèses régionales étayées et alimentent une réflexion gîtologique actualisée s'appuyant sur une approche pluridisciplinaire combinée. Une telle démarche a d'ores et déjà porté ses fruits et a permis la découverte d'une dizaine de concentrations aurifères à partir d'une exploration simultanée des informations alluvionnaires et géochimiques disponibles.

Thème 11 : TECHNIQUES SPECIFIQUES D'ECHANTILLONNAGE ET DE PREPARATION DES PRELEVEMENTS

Topic 11 : SPECIFIC SAMPLING AND SAMPLE PREPARATION PROCEDURE

Diagnostic précoce de la signification gitologique des anomalies stratégiques par analyse ICP des minéraux lourds.

D. Artignan

Depuis quelques années, la prospection géochimique stratégique en sédiments de ruisseau a vu ses performences sensiblement améliorées. En effet, un échantillonnage bien maitrisé, suivi d'une analyse multiélémentaire sensible et fiable, fournissent des données dont l'interprétation se révèle, après contrôle, correspondre à des minéralisations d'intérêt très divers. Une sélectivité accrue et une hiérarchisation plus précoce s'imposent car le déclin des moyens affectés à la recherche minière ne permet plus le suivi systématique et contraignant de toutes les anomalies mises en évidence ; il oblige à l'inverse de concentrer les efforts sur les cibles dont le devenir économique reste ouvert.

Afin de poser un diagnostic typologique précoce sur les anomalies géochimiques issues de la prospection régionale, la démarche choisie a consisté à isoler et à amplifier la composante détritique du signal géochimique, par séparation et analyse ICP des minéraux lourds contenus dans des sédiments de ruisseaux. En effet, les études méthodologiques conduites ces dernières années ont bien démontré que seules quelques phases minérales privilégiées sont responsables des anomalies géochimiques. Après avoir testé différents modes de concentration de ces phases (tamisage, séparation électro-magnétique, traitement gravimétrique) c'est la voie gravimétrique par liqueur dense qui a été retenue.

Les zones anomales régionales dont on veut préciser la signification gîtologique et donc la portée économique, font l'objet d'un rééchantillonnage restreint ; les échantillons, grossièrement débourbés sur le terrain, sont traités ensuite en laboratoire, avec séparation de la fraction de densité 2,9. Après examen sous la binoculaire, le concentré est analysé à l'ICP.

Le traitement des données analytiques fait en premier lieu appel au codage binaire rendu nécessaire par leur caractère discontinu voire erratique. L'information ainsi restructurée est ensuite soumise à une analyse factorielle des correspondances dont le but essentiel est de positionner chaque échantillon dans un nouvel espace multivariable, continu, où l'application des techniques de classification est possible. On procède alors à cette classification, par le biais des programmes spécialisés qui, dans l'espace factoriel, vont comparer chaque résutat nouveau à des données de référence correspondant à des minéraisations connues.

Une application au Massif Central (France) de cette approche a effectivement permis de classer un certain nombre d'anomalies jusqu'alors "anonymes", en les attribuant à un type gîtologique précis. Par exemple, sur le plateau d'Aigurande, on a pu distinguer les anomalies à métaux de base susceptibles de correspondre au modèle "sulfures massifs polymétalliques en environnement volcano-sédimentaire" de celles liées à des minéralisations discrètes et sans intérêt, situées à la base des lambeaux du Lias transgressif. De même, une similitude entre certaines anomalies nouvelles en or et la réponse géochimique obtenue dans les mêmes conditions dans l'environnement du gîte d'or du Bourneix a pu être dégagée.

Ainsi, une lecture plus fine du signal géochimique émis par des échantillons anomaux permet, par une démarche analogique, une hiérarchisation très précoce des anomalies stratégiques, et donc une meilleure programmation des travaux de suivi.

Till geochemistry at the great Gull scheelite prospects, New Foundland, Canada. A case history in orientation and discovery.

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R.J. Snow

Exploration for tungsten has been ongoing since 1983 in the Great Gull Lake area ($\sim$1,500 km^2), Bay d'Espoir Highway, central Newfoundland, Canada. Two tungsten prospects were discovered which are both hosted by metasediments, but are markedly different in their mode of occurrence. The South Quarry prospect, discovered during geological reconnaissance work, consists of granite-related, scheelite-bearing, quartz-feldspar veins. In contrast, the Camp Ten prospect, discovered four kilometers to the south by till geochemistry, comprises stratiform disseminated scheelite, in calc-silicate horizons.

Bedrock exposure is sparse due to an extensive cover of glacial overburden. As a result, the glacial history of the area was studied to provide a framework for exploration using till geochemistry. The study incorporated a review of the available literature, striation measurements, till fabric analyses, boulder tracing, glacial sediment classification and airphoto interpretation of landforms. Backhoe trenches were used to examine the overburden. Data from these studies indicate regional ice movement initially toward the east (110°), followed by movement to the south (150° to 190°), and finally by movement toward the northeast (50°). The last ice movement appears to occur only in the north of the study area. In the area of the tungsten prospects, glacial features and sediments are predominantly related to the middle ice movement direction (170° to 180°). This movement appears to have removed any sediments from the earlier glacial event, and the last glacial event did not extend as far south as the area of the tungsten prospects. Ribbed moraine dominates the glacial terrain. Tills in the study area include many genetic classes which reflect their complex depositional history in subglacial, supraglacial and ice marginal environments. The predominant overburden type sampled on the property was a moderately to highly compact sandy-silt subglacial lodgment to melt-out till containing abundant angular clasts of graywacke and slate of relatively local origin.

In 1983, a geochemical orientation survey was carried out to determine the most informative and cost-effective elements and sample medium to use in the search for tungsten. Seventeen backhoe trenches were excavated to depths of up to three meters. The complete profile of BF-horizon soil and glacial sediments was sampled in each trench to the bedrock. A split of every sample was sieved to $< 2{,}000\,\mu m$ and pulverized to $< 75\,\mu m$. Selected samples were : a) sieved to three size fractions $-< 2{,}000\,\mu m, \geq 180\,\mu m$ (ground to $< 75\,\mu m$), $< 180\,\mu m, \geq 75\,\mu m$, and $< 75\,\mu m$; b) prepared by heavy liquid separation (500 g of $< 2{,}000\,\mu m$ through a heavy liquid of SG 2.96) ; and c) concentrated using a Wilfley shaker table and heavy liquid of SG 3.3. Also collected, on grids in the vicinity of the trenches and over a portion of the claim block, were BF-horizon soil and underlying till samples. The former were sieved to $< 180\,\mu m$ and the latter were sieved to $< 2{,}000\,\mu m$ and pulverized to $< 75\,\mu m$. The samples were analyzed for Cu, Pb, Zn, Ag, Mo, Mn and Fe (HNO_3/HCl digestion, atomic absorption spectrophotometry : F^- (ion-selective electrode) : Au (fire assay, atomic absorption spectrophotometry) ; and W (fusion and colorimetry).

The results of the orientation studies indicated that the most effective procedure for outlining the tungsten mineralization and associated glacial dispersal trains was to collect whole till samples, below the level of soil development, and obtained 200 g of the $< 2{,}000\,\mu m$ fraction. This material was then pulverized to $< 75\,\mu m$, to help homogenize it and remove "nugget" effect problems, before subsampling for W analyses. Tungsten itself was clearly the only element effective for delineating the tungsten mineralization and associated dispersal trains. No one size fraction of the tills showed any clear pattern of W enrichment related to mineralization. Various size fractions of BF-horizon soils contained generally erratic and low levels of W, most being at or close to the analytical detection limit. This was interpreted to be due to W concentrated in a thin layer within the BF-horizon due to sieve deposition by abundant precipitation washing the scheelite grains down from the surface horizons of the soil. However, confident identification and sampling of this layer was virtually impossible. Although heavy mineral concentrates did clearly define the zone of mineralization and associated dispersal trains, the high shipping and preparation costs and sometimes long wait for the geochemical data offered no exploration advantage.

Subsequently, the entire claim block and parts of the surrounding region were explored using whole till geochemistry (sieved to<2,000μm, 200 g ground to<75μm, and a subsample analyzed for W). The objectives were to define the pattern of glacial dispersal from the known tungsten mineralization (i.e., South Quarry) and to explore for additional tungsten mineralization on the property and within the region. Data from the survey indicated a large, 2 to 3 kilometer wide, dispersal train of W-rich tills, extending 8 to 10 kilometers southward from the South Quarry tungsten prospect. However, the width of the dispersal train was considered to be greater than could be attributed to the area of subcropping tungsten mineralization at the South Quarry. Further prospecting and boulder tracing based on anomalous W in whole till data resulted in the discovery of boulders containing stratiform tungsten mineralization approximately four kilometers south of the South Quarry. These boulders appeared to be part of a glacial dispersal train from an unknown source within the dispersal train from the known mineralization at the South Quarry. Early in 1985, a backhoe trenching program was carried out based on the stratiform tungsten boulder train and the data on anomalous W in till. This resulted in the discovery of buried stratiform tungsten mineralization in bedrock, later confirmed by diamond drilling. The overall grade, tonnage and resultant economic potential of the stratiform tungsten mineralization are being evaluated.

Effet du cycle biogéochimique sur la distribution des éléments traces (Cu, Pb, Zn, Co, Ni, Ca) dans les sols de l'étage montagnard vosgien.

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E. Jeanroy
C. Rougier

Introduction

Il est bien connu en prospection géochimique tactique des régions tempérées que les horizons superficiels humifères des sols concentrent parfois certains éléments. On admet que le cycle biogéochimique intervient comme agent de concentration. Le cycle biogéochimique désigne le retour, généralement annuel, sur la surface du sol d'une grande partie des éléments prélevés en profondeur par les racines. Cet apport s'oppose aux pertes qui s'effectuent par entraînement et par séquestration définitive d'éléments dans des plantes ou parties de plantes non restituées au sol.

Le cycle implique un bilan qui présente plusieurs possibilités selon les propriétés de l'élément considéré, le type de végétation et le mode d'humidification des litières. Le jeu du cycle peut aboutir à une concentration ou un appauvrissement superficiel de l'élément. Il peut aussi n'avoir aucun effet apparent ou mesurable.

A travers des écosystèmes-types de l'étage montagnard, on vise à saisir l'impact du cycle biogéochimique sur les concentrations des éléments en traces (Cu, Pb, Zn, Ni, Co, Cr) des matériaux acides soumis à l'action d'une pédogenèse organique. Pour cela, on a procédé à une étude de la distribution des éléments-traces dans une sélection de sols développés sur des produits d'altération du granite des ballons (Vosges - France).

CONTEXTE GEOLOGIQUE ET COUVERTURE PEODOLOGIQUE

L'échantillonnage s'est effectué sur le complexe plutonique des ballons intrusif dans la série viséenne volcano-sédimentaire et concerne principalement la zone centrale constituée de granite porphyroïde à biotite et hornblende. Dix sept profils de sols ont été prélevés selon trois transects topographiques recoupant parfois des secteurs minéralisés de type porphyry-Cu-Mo (transect de Château Lambert et des Oeillets).

La couverture pédologique comporte deux types de sols : aux sols bruns acides qui prédominent à l'aval des toposéquences (altitude comprise entre 650 et 760 m) s'opposent des sols bruns ocreux humifères qui constituent les sols-climax de la hêtraie et hêtraie-sapinière de l'étage montagnard supérieur (altidude : 800-1100 m).

La couverture pédologique s'est établie aux dépens de matériaux issus du remaniement souvent d'origine périglaciaire, des altérites du granite des ballons. Ce matériau, et non point le granite lui-même, constitue le matériel de référence que nous avons choisi. Nous l'appelons horizon C ou roche-mère initiale.

L'horizon superficiel est humifère (horizon A_1). Il s'agit d'un mull dans les sols bruns acides et d'un moder dans les sols bruns ocreux. Entre la roche-mère et l'humus superficiel se développe un horizon intermédiaire (horizon B ou (B) caractérisé par une argilisation progressive per ascensum du matériel minéral initial.

METHODE

Les horizons des 17 profils pédologiques ont été séchés à l'air et tamisés à 2 mm. Les analyses pédologiques (teneurs en argiles, en carbone organique) ont été faites sur la fraction inférieure à 2 mm. Cette même fraction, pulvérisée, a été calcinée à 500°C et les teneurs en éléments-traces (dont Cu, Pb, Zn, Ni, Co, Cr) de la poudre calcinée ont été déterminées en spectrométrie d'émission (C.R.P.B. Nancy et S.N.E.A.P., Pau).

RESULTATS

L'efficacité du cycle biogéochimique d'un élément est appréciée par la variation de la teneur de cet élément depuis la roche-mère jusqu'à l'horizon A_I. Plusieurs démarches sont possibles pour mettre en relation les variations des teneurs et celles des constituants principaux du sol (argile-matière organique).

1.- En établissant la teneur moyenne de tous les horizons C et A_I on montre que le plomb est l'élément qui révèle le mieux l'influence du cycle biogéochimique comme agent de concentration dans les horizons humifères superficiels. La teneur moyenne y est significativement plus élevée (145 ppm) que dans l'horizon C (35 ppm, cf. tableau I).

Moyenne	Cu	Pb	Zn	Ni	Co	Cr
Horizons A_I	206±240	145±82	78±31	11± 2	48±26	98±33
Horizons C	418±430	35±31	60±24	25±27	33±12	94±40

Le zinc présente une accumulation peu sensible alors que Ni, Co. Cr sont peu affectés par le cycle.

Pour le cuivre, l'échantillonnage des roches-mères conserve parfois la trace des minéralisations (malachite) de sorte que l'on note une forte dispersion des teneurs. Dans les horizons A_I, la moyenne se trouve abaissée mais la dispersion demeure. En fait, on a observé que dans les sols où les teneurs des horizons C sont faibles (50 ppm), il y a enrichissement en A_I et le bilan devient positif. Par contre, il est très négatif quand les roches-mères sont minéralisées (500 ppm).

2.- On définit un coefficient k_I de variation d'un élément comme le rapport de la teneur en A_I sur celle des roches-mères. Un coefficient caractérise un profil. On évalue également les coefficients K des argiles et de la matière organique de chaque sol. Des relations sont établies entre les coefficients relatifs aux éléments et ceux concernant l'argile et la matière organique.

Le plomb se distingue des autres éléments. Les coefficients de variation sont supérieurs ou égaux à un, pour 60 % des profils échantillonnés.

On montre que la matière organique est le cosntituant du sol qui contrôle, plus que tout autre, l'efficacité du cycle biogéochimique, notamment celui du plomb. En effet, une corrélation existe entre la variation des teneurs en Pb et celle de la matière organique des sols. Dans la zone bioclimatique d'étude on peut affirmer que le plomb se concentre en surface d'autant plus intensément que les sols sont plus humifères.

CONCLUSION

L'accumulation du plomb dans les humus des sols forestiers acides est un fait connu des prospecteurs (BRUCKERT et al., 1979). La raison n'en est pas totalement élucidée, mais il est indéniable que Pb moins complexable que Cu présente par contre une très forte affinité pour les produits polysaccharidiques (MENCH et al., 1987) de la rhizosphère des plantes, abondants dans les humus.

REFERENCES

BRUCKERT S., CACHAU-HEIREILLAT F., CAPDECOMME H. et GUILLET B. (1979) - Intervention du cycle biogéochimique dans la genèse des concentrations anomaliques du plomb. Exemple de la vallée du Rahin (Haute-Saône, France). Bull. Centre Recherche, Pau, 3, 281-297.

MENCH M., GUILLET B., MOREL J.L. et GUCKERT A. (1987) - Metal binding properties of soluble exsudates of law molecular weight produced by maize roots. J. Soil Sci. (soumis).

Overbank deposits as a sampling medium in geochemical mapping.

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Studies of fluvial erosion and sediment sources in Norway have led to the conclusion that in glaciated terrain, streams tend to erode at certain point sources along the stream channel. Stream sediments, sampled in a traditional way, therefore, represent a restricted number of locations and not the whole drainage system. In many cases it may even be that samples taken at intervals along a drainage system are duplicates of samples from the same sediment source. These considerations have led to a new sampling technique involving sampling of overbank deposits.

During the annual springflood streams collect sediments from many point sources, and at occasional catastrophic floods active erosion occurs in the whole drainage basin. These sediments are deposited and preserved on the flood as overbank deposits.

Samples of overbank material, therefore reflects much larger areas than the traditional active stream sediment does reducing the number of samples and costs of regional geochemical mapping. It also opens possibilities for finding natural geochemical distribution patterns in heavily polluted areas, by sampling the deep oldest part of the overbank stratigraphy.

The geological survey of Norway has produced a geochemical atlas of Norway (300,000 km^2) based on analysis of 700 samples of overbank deposits. The geochemical maps have disclosed surprising and unexpected patterns. Large-scale structures so far unknown by mapping geologists have been indicated. Some of the large geochemical provinces which have been delineated appear to be promising prospecting areas. It is thought that the technique of using overbank deposits in geochemical mapping makes it possible and meaningful to produce a geochemical atlas of the world.

Use of stream sediment elemental enrichment factors in geochemical exploration for Uranium and carbonatite deposits, Arkansas - USA.

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Three hundred and thirty-five stream sediment samples were collected in central Arkansas. U.S.A., during a reconnaissance survey as part of the National Uranium Resource Evaluation (NURE) program. The study area covers 1575 mi^2 (approximately one-half within the Ouachita Mountain Region and one-half in the Gulf Coastal Plain Region). The Gulf Coastal Plain Region is composed primarily of Tertiary and Quaternary sand, clay marl, shale and limestone ; whereas, the Ouachita Mountain Region is characterized by intensely folded and faulted Paleozoic shale. sandstone and novaculite. Although alkalic igneous rocks occur in both regions predominantly as dikes and sills, several larger intrusions are present. Two of the larger intrusions, Magnet Cove and Potash Sulfur Springs, located in the Ouachita Mountain Region are zoned and have associated carbonatite. Lignite deposits occur scattered throughout the Gulf Coastal Plain Region.

The stream sediment samples were sieved into four size fractions, < 40, 40-100, 100-200, < 200 mesh, and analyzed by neutron activation analyses for rare earth elements (REE), Ti, V, Th, U and nineteen other elements. The two smaller size fractions yielded higher elemental values and produced more distinct anomalies. Because the < 200 mesh size yielded slightly better results, this size fraction was used to evaluate geochemistry as an exploration method for uranium and carbonatite deposits in central Arkansas.

Based on geological factors and statistical analyses of the stream sediment chemical compositions, four distinct geochemical areas were identified. A multi-element map using uranium and pathfinder elements for uranium and carbonatite deposits was constructed using the "total enrichment index" (sum of the individual enrichment values for REE, V, U, and Th). In order to minimize the effect of concentration and to emphasize the anomalous aspect of the elements for the multi-element map, the raw data for each area were normalized to "enrichment values" where 1 and 0 represent samples with maximum and minimum concentrations, respectively. This multi-element map delineates three halos. Two of the halos are located in the Ouachita Mountain Region, one near Magnet Cove extending westward toward Potash Sulfur Springs and the other is located in the Womble Shale. The third anomalous area is located in the Gulf Coastal Plain in the Wilcox Formation, downstream from a lignite deposit that contains anomalous concentration of rare earth elements and other elements. R-mode cluster analysis confirms that these three halos are produced by three distinctly different geochemical environments. Single element maps proved to be useful in distinguishing these three environments, alkalic igneous rocks, shale and lignite. A map based on Ti concentrations delineated the igneous rock and lignite areas, i.e. the halo in the Woble Shale was not indicated. The igneous halo can be distinguished from the lignite halo by much higher Ti concentrations associated with the igneous rocks. A V map also is useful in distinguishing the lignite and igneous halos. as only the igneous halo is reproduced on this single element map. Thus, multi-element geochemical maps based on "total enrichment index" when used in conjunction with appropriate single element data, appear to be promising for locating uranium carbonatite deposits in distinctly different geological regions of central Arkansas and similar environments elsewhere.

Enrichment of arsenic and sulphur in the finest fractions of crushed rock samples ; an experimental study.

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P. Lestinen
A. Hartikainen

According to the literature (Mason, 1966 ; Wedepohl, 1978 ; Rose et al., 1979) arsenic contents are much higher in soil than in bedrock. Our observations in glaciated terrain indicate that this trend is also clear - but not unequivocal - as far as bedrock and the finest fractions of till are concerned. Data for sulphur is not so clear in the literature, but it seems that similar enrichment does not occur. In this study the effect of mechanical crushing on As and S enrichment was examined.

Studies were made for ten samples from the Archean bedrock of eastern Finland. Samples were crushed in a jaw crusher in ordre that the final grain-size distribution corresponds as closely as possible to the grain-size distribution of till. The ≤ 64 µm and 64-500 µm fractions - normally used in geochemical prospecting of till in Finland - were sieved from the crushed samples. The ground total sample and the sieved fractions were analyzed for arsenic by AAS with EDL-hydride generator and for sulphur by Leco-sulphur titrator. Polished thin sections were also studied microscopically.

The results indicate that in most cases arsenic is strongly enriched in the finest fraction. For the granitoids, plagioclase porphyry and graywacke the enrichment of arsenic was fifteenfold. In the gabbroic rocks no enrichment was observed. For the samples from banded iron formation the enrichment is clear but not very strong. On the contrary, sulphur shows a different behaviour from arsenic : the enrichment in the fine fractions is less important but was also noticed in the gabbroic samples.

A common feature of the samples which showed the strongest enrichment was the high quartz content. Possibly rocks containing plenty of quartz grains are brittle and split along grain boundaries, releasing the fine material between the grains. Most of the arsenic seems to be enclosed in this material. According to our results, sulphur enrichment depends on the grain-size whereas As does not correlate with the same parameter. For both elements there appears to be no correlation between the element content and the enrichment coefficient.

The study brought out features which help in the interpretation of geochemical till data. It also indicated that for prospecting purposes, it is better to measure arsenic content in the finest fraction of till. Indeed, the finest fractions display the largest range for As contents, and therefore more distinct anomaly patterns may be distinguished. The analytical data is also more reliable because the concentrations are at a higher level.

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ADDENDUM

PRESENTATION DES POSTERS
POSTER PRESENTATIONS

Thème 1 : Approches combinées d'exploration
Topic 1 : Integrated exploration techniques

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A new approach in geochemical exploration : the establishment application and development in China of geochemical and mineralogical techniques.

Thème 6 : Prospection sous recouvrement allochtone
Topic 6 : Exploration in transported overburden

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W. YANG and F.R. SIEGEL

Geochemical exploration for chromite deposits, Piedmont Upland Province, Maryland, USA.

A new approach in geochemical exploration : the establishment, application and development in China of geochemical and geochimical and mineralogical techniques

W. Gongque
G. Yuanming
M. Huan

Chromium is a strategic and critical metal in industrial development. Commercial sources of chromium are limited to relatively few countries and the present and projected demand for the metal is growing. It is in the interest of the industrial nations which lack identified economic resources yet require the metal, and of the developing nations that need non-traditional strong value exports with established future markets, to explore for chromite mineral deposits, determine their potential, and plan for their development.

Podiform chromite orebodies that occur in the Piedmont Uplant province of Maryland, are relatively small and have very irregular shapes. Regional exploration for such deposits is based on geological mapping to identify ultramafic host rocks and on evaluations of heavy mineral concentrates in stream-sediments together with magnetic and gravimetric geophysics. The effectiveness of these techniques has been limited because of the small size of the podiform deposits and their direct relations with ultramafic rocks with the associated magnetite component. In this study, stream bottom sediments (-100 mesh size fraction), totally dissolved and extracted with cold 3 % HNO_3, and suspended sediments, were analyzed for the elements Cr, Mg, Ni, Co, Fe, Mn, Zn, Cu and Pb to determine the effectiveness of a multielement-multisample type approach in identifying chromite targets areas for detailed exploration by soil geochemisry, botanogeochemistry and CLF-EM. Suspended sediments were studied because of the report by Gladwell and Lett (1985) that in the exploration for tin, there was a preferential partitioning of fine-grained cassiterite (s.g. = 7.0) to the suspended load so that the tin anomalies, contrasts and dispersions were increased as compared to the bottom stream sediment. Chromite (s.g. = 5.1) might be expected to show similar relations between bottom and suspended stream sediments.

The elements Cr, Co and Ni can be used as multielement indicators in bottom stream sediments for chromite deposits in the Soldiers Delight serpentine district, Baltimore Country, Maryland, and should be equally indicative in areas where the geologic, topographic, and climatologic conditions are similar. Chromium in the total dissolution samples is a stronger indicator element than Cr in the extracted samples whereas Co has good pathfinder anomaly patterns in both sample types. The Fe in extracted samples shows a good correspondence and Ni in this suite a fair relation to chromite mineralization. A combining of data from both sample types yield reliable results in geochemical prospecting for chromite deposits using bottom stream sediment. Chromium and Ni in the suspensate samples have anomalous values associated with known placers but their anomalies are more dispersed in the study area so that suspensates may be better suited in this case for broader regional surveys compared to bottom stream sediments. Cluster analysis suggests primary rock-mineral associations between Mg, Ni, Cr and Co in the total dissolution suite and between Ni, Co, Cr and Mg in the suspended mineral suite. Absorption by Mn oxides/hydroxides is suggested by the cluster relation between Mn, Fe and Zn in the total dissolution suite and suspended mineral suite. Source areas for placer chromite have been targeted for detailed geochemical exploration.

The strategic and critical metals heavily used in industry such as chromium, nickel, cobalt and manganese which are essential alloy elements in heat-, corrosion-, and wear-resistant materials, plus the platinum-group metals which are important in catalysis and for electrical applications should be high priority commodities in the geochemical exploration for mineral deposits. This is applicable both to those countries which use them in the aerospace, chemical, fuel production, mining, mineral processing, automotive, electrical transmission, and other high technology industries, and to those countries in development which can use these and other metals for export to growing markets as well as for developing their own industrial bases. The multi-element-multisample type strategy in regional or follow-up geochemical exploration increases the probability of finding mineral deposit targets for detailed studies.

Secondary copper compounds in till in the Löytösuo area, Ylikiiminki, northern Finland

V. Peuraniemi
R. Aario

The study area belongs to the Proterozoic Kiiminki schist belt in northern Finland. The main rocks types are greywackes, mica schists, black schists, dolomites, skarns and basic volcanics. The surface of the bedrock has weathered in some places.

The overburden of the study area consists mainly of till, the thickness of which is 3-7 m. In some places there occur till beds. The last ice movement has taken place from west-northwest.

In order to fine sulphide orebodies various geochemical methods were used. The main geochemical method was till geochemistry. Till samples from near the bedrock surface were taken using quite a dense sampling grid. Several copper anomalies were found, one in the bog area, named Löytösuo. Maximum copper contents in the till fines were over 400 ppm.

The mineralogy and mineral chemistry of a copper anomaly found were studied. The sand fractions of the anomalous samples were separated by heavy liquid and the heavy fractions investigated using optical microscopes, a scanning electron microscope equipped with EDS, an electron microprobe and X-ray diffraction. Selective chemical extraction studies were also made.

A rare mode of occurrence of copper, as iodide, was founded in one sample.

The chemical composition of the copper iodide found was Cu 34.30 %, I 65.85 %. This is very close to the stoichiometric composition of marshite, CuI (Cu 33.36 %, I 66.64 %). Chitayeva et al. (1971) have described the occurrence of mineral of the marshite-miersite group in the supergene zone of a chalcopyrite deposit. Iodine bearing mixture grains were also found (Fe, Cu, Si, I, Al, S, Mg, Ca, K)

Secondary chalcopyrite was found in three forms : 1. enveloping primary minerals, for example some primary chalcopyrite grain coated with a secondary chalcopyrite layer were found and this layer has often plastered silicate mineral grains ; 2. filing cracks in pyrite ; 3. as colloform-textured ooids, the surface morphology of which is dimpled.

The electron microprobe analysis from an ooid gave Cu 29.96 %-33.34 %, Fe 26.00-27.92 % and S 29.75-32.34 %, the rest being presumably water. Binda and al. (1985) have described similar sulphide ooids from a Proterozoic arenite bed in Alberta, Canada.

On the basis of their texture and composition these secondary copper compounds have clearly originated in the till by precipitation from circulating groundwater. Such copper compounds may also be an important mode of occurrence of copper in soils in unglaciated areas and may have a bearing on the origin of sedimentary copper deposits.

Iodine can be used as an additonal indicator element in geochemical exploration for sulphide ore deposits, as e.g. Fuge and al. (1986) have suggested.

References :

BINDA O.L., KOOPMAN H.T. and SCHWANN P.L. (1985) - Sulphide ooids from the Proterozoic Siyeh Formation of Alberta, Canada, Mineral Deposita n° 20, pp. 43-49 ;

CHITAYEVA N.A., MILER A.D., GROSSE Yu. I. and CHRITYAKOVA N.I. (1971) - Iodine distribution in the supergene zone of the Gay chalcopyrite deposit. Geochem. Internat. n° 8, pp. 426-436 ;

FUGE R., ANDREWS M.J. and JOHNSON C.C. (1986) - Chlorine and iodine, potential pathfinder elements in exploration geochemistry. Applied Geochemistry. Applied Geochemistry n° 1, pp. 111-116.

Prospection géochimique pour l'étain et le tungstène au Rwanda

A. Ivanov

Une méthode de prospection géochimiqupour Sn et W basée avant tout sur l'interprétation d'anomalies géochimiques composites a été mise en oeuvre lors d'un projet de recherches minières au Rwanda.

Le Rwanda est constitué d'un socle précambrien, d'âge burundien et rusizien (schistes, quartzites) et de granites variés de même âge.

Les minéralisations en Sn et W sont liées aux champs pegmatitiques et filoniens accompagnant des granites : elles sont exprimées sous forme de cassitérite, en général associée à la columbo-tantalite et au béryl, de ferbérite et plus rarement de scheelite et de minéraux secondaires tels que l'antoinite et la tungstite. Les sulfures (pyrite, chalcopyrite, arsénopyrite) participent à l'état de trace à ces paragenèses. Les minéraux de tungstène sont disséminés dans les filons de quartz encaissant les schistes graphiteux et plus rarement dans les schistes et les latérites.

Les échantillons de roche ont fait l'objet d'une analyse multiélémentaire permettant la définition d'auréoles de dispersion pour Sn, W, Mo, Be, Li, Rb, B, F, Nb, Th et As. Deux groupes d'anomalies, définis statistiquement au niveau de deux et trois sigma, correspondent respectivement à des anomalies lithologiques et à des anomalies métallogéniques.

La vérification de 438 champs anomaux, découverts par la prospection stratégique, a permis de dégager six localités d'intérét tactique : Muséni, Rukara, Bare, Shori, Nyamutera et Gachaki-Ntarama.

Les minéralisations sont représentées par des pegmatites à cassitérite, des filons de quartz à cassitérite et wolframite et des filons de quartz à ferbérite et antoinite. L'interprétation des auréoles composites de dispersion primaire en roches réalisée sur trois gisements de référence (Musenyi, Rutongo, Schiorong) a montré la spécialisation géochimique de trois types de minéralisations :

Le premier est caractérisé par l'association Be, Nb, Th et Rb, le second par la présence d'As, Mo et une importante dispersion en Sn, W, B et As dans les roches encaissantes, le troisième par la présence d'As, Pb, Mo, l'absence de Li et une importante diffusion en W dans les roches encaissantes. Il y a une liaison géochimique évidente de Sn avec B, F et Be, de W avec As et une liaison plus aléatoire de Sn avec As.

Les auréoles primaires en roches de gisements pris comme référence et celles observées dans les zones d'intérêt tactique sont caractérisées par des anomalies fortes en Sn, W, Nb, Li, F, B et As : cela confère aux prospects retenus un intérêt métallogénique potentiel.

L'étendue des anomalies géochimiques suit dans certains cas une zonalité : U (granite) - Sn (bordure granitique) - W (périphérie ou plus loin), qui est caractéristique pour les minerais liés aux granites.

De même, les hozirons de quartzites Ndula sont presque toujours présents à proximité de gisements et des anomalies en Sn et W.

L'analyse du contexte géochimique nous conduit ainsi à formuler une hypothèse génétique : les minéralisations de Sn et de W au Rwanda sont le résultat d'une mobilisation profonde effectuée par le magmatisme granitique développé dans les zones d'une plate-forme ancienne, enrichies en B, F, W, Sn et en métaux rares.

Geochemical exploration for chromite deposits, Piedmont Upland Province, Maryland, USA

W. Yang
F.R. Siegel

Since 1980, a new approach in geochimical exploration has been established in China. This approach got rid of the traditional pattern of geochemical prospecting which takes elements as the object of study and is the extension of geochemical prospecting techniques in a new field. Combining exploration geochemistry with prospecting mineralogy, it is a new method of mineral exploration, unaffected by the geological and climate circumstances and involving a series of modern techniques to obtain data from rocks and minerals (nuclear paramagnetic resonance, electron paramagnetic resonance, Mössbauer effect, ultrared absorption spectrum, enclosure mineralogy and heat-light emission etc). Used to draw a large quantity of microscopic and ultramicroscopic information contained in minerals of all sources, it can guide mineral prospecting and the locating of target areas.

Having applied this technique, China in recent years has achieved noteworthy results in some typical mining areas such as Xinjiang Altay scarce metal pegmatitic deposits, Jinduizhen molybdenum deposits in Shaanxi, Shaxi porphyry copper in Anhui, Panzhihua iron deposits in Sichuan and Daye iron deposits in Wuhan etc., cases of application and results are given in this paper.

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A new approach in geochemical exploration : the establishment, application and development in China of geochemical and geochimical and mineralogical techniques

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Metal abundances in the amphibolites of Ife-Ilesa Schist Belt of S.W. Nigeria in relation with gold mineralization

T.R. AJAYI
D.O. OGBEIDE

Alluvial gold, in the Ifé-Ilesa Schist Belt, is associated to an amphibolite complex containing mainly amphibolites. Petrochemical studies show that these amphibolites are metamorphosed tholeiitic and calc-alkaline basalts related to back-arc marginal basin.

Early geochemical exploration work includes regional stream-sediment and soil surveys. Further rock geochemical studies utilized "total" element data and laid emphasis on the geotectonic setting of the area, without considering in details the factors responsible for metal distribution in the samples.

The preliminary study which is described hereafter investigates the distribution of Zn, Cu, Co and Cr in the amphibolites of Ife-Ilesa Schist Belt, with the following objectives :

1. to determine whether the metal distribution is related to variability due to silicate fractional crystallization on mineralizing processes ;
2. to determine the levels of enrichment of these metals in relation to possible mineralization and
3. to provide basic information and assess its application to the study of primary dispersion in this area.

These objectives are considered important since the level of gold concentration in this area is of less economic value compared to typical Archean greenstone belts.

Partial extraction with aqua regia was carried out on thirty selected bedrock samples. The partially extractable, Cu, Co and Cr were compared to available total analysis and radio-chemically determined gold contents in ten of these samples.

The results reveal normal background values of these metals. Varying proportions of the total concentration are released by the partial extraction. These proportion respectively average 7 %, 37 %, 49 % and 67 % for Zn, Co, Cu and Cr respectively, thus reflecting the relative proportions of their presence in the sulphide form.

Gold concentrations in the ten randomly selected amphibolite samples range between 0.3 - 1.7 ppb with a mean of 0.4. Compared to the averages of 2.55 ppb for tholeiites, 1.82 ppb for mafic and 0.92 ppb for ultramafic rocks, such a mean value is low and much lower than 0.2954 ppm for 59 rhyolite porphyries of Cinola Carlin-type gold deposit.

The relationships between the metals and of the metals with gold were weak estimated by calculating the correlation coefficients. Gold seems to show significant negative correlation with Co and a relatively low negative correlation with Cr, whilst it is moderately (0.423) positively correlated with Cu. Chromium is significantly though moderately positively correlated with Co and Zn.

These figures should be considered carefully, as only a few samples were involved.

For geochemical exploration purposes, this partial extraction technique is applicable as a fast and relatively cheap method in assessing the mode of occurrence of ore and pathfinder elements. However, more detailed studies will be needed for the Ife-Ilesa area. It is believed that in areas with relatively low levels of concentration of ore elements such as this area, anomaly/background contrasts are normally low. This could have accounted for the failure of qualitatively evaluated routine geochemical data in delineating potential areas of gold mineralization.

Thermal and energy factors of metal concentration in igneous plutons : an application to metallogenic analysis and exploration

V.G. ZOLOTAREV

Two extreme modes of ore formation in pluton environments can be recognized by the different degree for participation of fluids of magmatic and meteoric origin. In one case magmatogenic fluids dominate in metal concentration and in ore deposition during the stages of magma crystallization yielding to meteoric fluids at a late stage when a residual thermal field of a pluton exist. In the other ore-forming convective system of meteoric origin prevails from the very beginning after magma emplacement.

The numerical modeling technique applied for the study of geochemical systems opens the possibilities to forecast promising areas by revealing factors of metal concentration in thermal gradient fields of intrusive bodies. Metal behaviour is analysed against a background of spatial-temporal dynamics of the following processes : crystallization of magma chambers, development of thermal and energy fields and of thermal fracturing, as well as the origination of anomalous thermal and energy regimes favourable for metal accumulation.

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POSTERS

To be joined to the addendum :

1. W. GONGQUE
   G. YUANMING
   M. HUAN

A new approach in geochemical exploration : the establishment, application and development in China of geochemical and mineralogical techniques.

2. W. YANG
   F.R. SIEGEL

Geochemical exploration for chromite deposits, Piedmont Upland Province, Maryland, USA.

(misplacement of titles and names of authors)

3. T.R. AJAYI
   D.O. OGBEIDE

Metal abundances in the amphibolites of Ife-Ilesa Schist Belt of S.W. Nigeria in relation with gold mineralization.

4. V.G. ZOLOTAREV

Thermal and energy factors of metal concentration in igneous plutons : an application to metallogenic analysis and exploration.

A ajouter à l'addendum (pour 1 et 2, permutation des titres et noms d'auteurs)

A new approach in geochemical exploration : the establishment, application and development in China of geochemical and mineralogical techniques

W. Gongque
G. Yuanming
M. Huan

Since 1980, a new approach in geochimical exploration has been established in China. This approach got rid of the traditional pattern of geochemical prospecting which takes elements as the object of study and is the extension of geochemical prospecting techniques in a new field. Combining exploration geochemistry with prospecting mineralogy, it is a new method of mineral exploration, unaffected by the geological and climate circumstances and involving a series of modern techniques to obtain data from rocks and minerals (nuclear paramagnetic resonance, electron paramagnetic resonance, Mössbauer effect, ultrared absorption spectrum, enclosure mineralogy and heat-light emission etc). Used to draw a large quantity of microscopic and ultramicroscopic information contained in minerals of all sources, it can guide mineral prospecting and the locating of target areas.

Having applied this technique, China in recent years has achieved noteworthy results in some typical mining areas such as Xinjiang Altay scarce metal pegmatitic deposits, Jinduizhen molybdenum deposits in Shaanxi, Shaxi porphyry copper in Anhui, Panzhihua iron deposits in Sichuan and Daye iron deposits in Wuhan etc., cases of application and results are given in this paper.

Geochemical exploration for chromite deposits, Piedmont Upland Province, Maryland, USA

W. Yang
F.R. Siegel

Chromium is a strategic and critical metal in industrial development. Commercial sources of chromium are limited to relatively few countries and the present and projected demand for the metal is growing. It is in the interest of the industrial nations which lack identified economic resources yet require the metal, and of the developing nations that need non-traditional strong value exports with established future markets, to explore for chromite mineral deposits, determine their potential, and plan for their development.

Podiform chromite orebodies that occur in the Piedmont Uplant province of Maryland, are relatively small and have very irregular shapes. Regional exploration for such deposits is based on geological mapping to identify ultramafic host rocks and on evaluations of heavy mineral concentrates in stream-sediments together with magnetic and gravimetric geophysics. The effectiveness of these techniques has been limited because of the small size of the podiform deposits and their direct relations with ultramafic rocks with the associated magnetite component. In this study, stream bottom sediments (-100 mesh size fraction), totally dissolved and extracted with cold 3 % HNO_3, and suspended sediments, were analyzed for the elements Cr, Mg, Ni, Co, Fe, Mn, Zn, Cu and Pb to determine the effectiveness of a multielement-multisample type approach in identifying chromite targets areas for detailed exploration by soil geochemisry, botanogeochemistry and CLF-EM. Suspended sediments were studied because of the report by Gladwell and Lett (1985) that in the exploration for tin, there was a preferential partitioning of fine-grained cassiterite (s.g. = 7.0) to the suspended load so that the tin anomalies, contrasts and dispersions were increased as compared to the bottom stream sediment. Chromite (s.g. = 5.1) might be expected to show similar relations between bottom and suspended stream sediments.

The elements Cr, Co and Ni can be used as multielement indicators in bottom stream sediments for chromite deposits in the Soldiers Delight serpentine district, Baltimore Country, Maryland, and should be equally indicative in areas where the geologic, topographic, and climatologic conditions are similar. Chromium in the total dissolution samples is a stronger indicator element than Cr in the extracted samples whereas Co has good pathfinder anomaly patterns in both sample types. The Fe in extracted samples shows a good correspondence and Ni in this suite a fair relation to chromite mineralization. A combining of data from both sample types yield reliable results in geochemical prospecting for chromite deposits using bottom stream sediment. Chromium and Ni in the suspensate samples have anomalous values associated with known placers but their anomalies are more dispersed in the study area so that suspensates may be better suited in this case for broader regional surveys compared to bottom stream sediments. Cluster analysis suggests primary rock-mineral associations between Mg, Ni, Cr and Co in the total dissolution suite and between Ni, Co, Cr and Mg in the suspended mineral suite. Absorption by Mn oxides/hydroxides is suggested by the cluster relation between Mn, Fe and Zn in the total dissolution suite and suspended mineral suite. Source areas for placer chromite have been targeted for detailed geochemical exploration.

The strategic and critical metals heavily used in industry such as chromium, nickel, cobalt and manganese which are essential alloy elements in heat-, corrosion-, and wear-resistant materials, plus the platinum-group metals which are important in catalysis and for electrical applications should be high priority commodities in the geochemical exploration for mineral deposits. This is applicable both to those countries which use them in the aerospace, chemical, fuel production, mining, mineral processing, automotive, electrical transmission, and other high technology industries, and to those countries in development which can use these and other metals for export to growing markets as well as for developing their own industrial bases. The multi-element-multisample type strategy in regional or follow-up geochemical exploration increases the probability of finding mineral deposit targets for detailed studies.

Metal abundances in the amphibolites of Ife-Ilesa Schist Belt of S.W. Nigeria in relation with gold mineralization

T.R. AJAYI

D.O. OGBEIDE

Alluvial gold, in the Ifé-Ilesa Schist Belt, is associated to an amphibolite complex containing mainly amphibolites. Petrochemical studies show that these amphibolites are metamorphosed tholeiitic and calc-alkaline basalts related to back-arc marginal basin.

Early geochemical exploration work includes regional stream-sediment and soil surveys. Further rock geochemical studies utilized "total" element data and laid emphasis on the geotectonic setting of the area, without considering in details the factors responsible for metal distribution in the samples.

The preliminary study which is described hereafter investigates the distribution of Zn, Cu, Co and Cr in the amphibolites of Ife-Ilesa Schist Belt, with the following objectives :

1. to determine whether the metal distribution is related to variability due to silicate fractional crystallization on mineralizing processes ;
2. to determine the levels of enrichment of these metals in relation to possible mineralization and
3. to provide basic information and assess its application to the study of primary dispersion in this area.

These objectives are considered important since the level of gold concentration in this area is of less economic value compared to typical Archean greenstone belts.

Partial extraction with aqua regia was carried out on thirty selected bedrock samples. The partially extractable, Cu, Co and Cr were compared to available total analysis and radio-chemically determined gold contents in ten of these samples.

The results reveal normal background values of these metals. Varying proportions of the total concentration are released by the partial extraction. These proportion respectively average 7 %, 37 %, 49 % and 67 % for Zn, Co, Cu and Cr respectively, thus reflecting the relative proportions of their presence in the sulphide form.

Gold concentrations in the ten randomly selected amphibolite samples range between 0.3 - 1.7 ppb with a mean of 0.4. Compared to the averages of 2.55 ppb for tholeiites, 1.82 ppb for mafic and 0.92 ppb for ultramafic rocks, such a mean value is low and much lower than 0.2954 ppm for 59 rhyolite porphyries of Cinola Carlin-type gold deposit.

The relationships between the metals and of the metals with gold were weak estimated by calculating the correlation coefficients. Gold seems to show significant negative correlation with Co and a relatively low negative correlation with Cr, whilst it is moderately (0.423) positively correlated with Cu. Chromium is significantly though moderately positively correlated with Co and Zn.

These figures should be considered carefully, as only a few samples were involved.

For geochemical exploration purposes, this partial extraction technique is applicable as a fast and relatively cheap method in assessing the mode of occurrence of ore and pathfinder elements. However, more detailed studies will be needed for the Ife-Ilesa area. It is believed that in areas with relatively low levels of concentration of ore elements such as this area, anomaly/background contrasts are normally low. This could have accounted for the failure of qualitatively evaluated routine geochemical data in delineating potential areas of gold mineralization.

Thermal and energy factors of metal concentration in igneous plutons : an application to metallogenic analysis and exploration

V.G. ZOLOTAREV

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