Why minus 80 mesh?

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The Editor wrote, "I am wondering if you know the history behind the selection of -80 mesh as the size for soil geochemistry?" I replied that I had heard two stories, both relating back to the early days (1950s) of John Webb and his students from Imperial College, London, working in Zambia:

1. It was the only size of bolting cloth they could get from Johannesburg; and,
2. It was a compromise good for both residual soils and stream sediments. That fraction contained both clays and fine grained weathering products, as well as slightly coarser fine fraction minerals. It tended to reduce the amount of 'dilutent' quartz.

It turns out that both of those reasons are true, but are not the whole story, which is much more interesting and involves the development of geochemical prospecting methods for both soils and stream sediments at the U.S. Geological Survey (USGS) during the 1940s and 1950s.

Herb Hawkes wrote up his memories of the start of geochemical prospecting studies at the USGS in his address to the Association's Appalachian regional meeting in Fredericton in 1976 (Hawkes 1976). As a response to a request for innovative project proposals from the USGS Chief Geologist in 1944 he, Helen Cannon and Lyman Huff made proposals to investigate geochemical and geobotanical prospecting methods. These were accepted and funds were provided in the 1946-47 budget to form a Geochemical Prospecting Research Group. They were joined by other USGS members including Hal Bloom, Frank Canney, Tom Lovering and V.P. (Pete) Sokoloff, amongst others (Hawkes 1996). Both Bert Lakin and Fred Ward, analytical chemists, joined at that time from the U.S. Department of Agriculture's Bureau of Plant Industry. Sokoloff was born in Tomsk, Russia in 1905, and came to the U.S. following the 1917 Revolution. He likely gained a degree in chemistry from the University of Arizona, and followed with a PhD in pedology from UC Berkeley in 1937 (Branagan 2007). He then worked for the U.S. Department of Agriculture before joining the USGS's Military Geology Unit, led by C.B. Hunt in 1943. When the geochemical prospecting research group was formed in 1946, he was a natural addition. His knowledge of Russian was invaluable in the light of the founding prospecting work of Russian geochemists in the 1930s and 40s, and he undertook the translation of several of their publications.

One of the Russian papers was 'Geochemical Methods of Prospecting for Ore Deposits' by Sergeev (1941). The soil sampling and preparation procedure described is clearly 'whole soil', i.e. the <2 mm fraction, which was pulverized to about 200 mesh (0.074 mm). Soil scientists have traditionally defined soil as material finer than pebbles, the dividing line between pebbles and sand being 2 mm diameter. Some sixteen years later Ginzburg (1957) wrote "… 1951 Manual of Metallometric Survey and 1955 MG and ON Manual differ in their recommendation of the particle size to be tested (in 1951: <1 mm; in 1955: <0.6 mm) which is assumed to be the same for any kind of ore". The sample material was pulverized to <0.1 mm prior to analysis. In Beus & Gregorian (1975), all the examples of the analysis of different soil and stream sediment sample size fractions are from studies outside of Russia. From this, it has to be concluded that 'minus 80 mesh' was not something learnt from the Russian literature.

Looking at African examples, Roberts (1953) describes field work undertaken in 1948 and 1949 in Nigeria and the analysis of 50 g aliquots of 'whole soil' containing fragments up ½ inch across. In the same area in late 1951, Hawkes (1954) sampled soils and the minus 80 mesh fraction was analysed following methods described by Bloom & Crowe (1953).

Thus, the focus returns to the USGS and the Geochemical Prospecting Unit (Hawkes 1976). The following text describing activities following formation of the Unit in 1946 is relevant "However, experiments in mining areas conveniently located with respect to the Survey's laboratory in Denver suggested that it [geochemistry] might be a very powerful ore guide when used on stream sediments. The idea of using traces of ore metals in stream alluvium as an ore guide had been investigated by Lovering et al. (1950) several years earlier in the San Manuel district of Arizona, which at that time had not been contaminated with mine dumps. In my own experimental work with this method near Denver, the fact that all the samples I took were contaminated to a greater or lesser extent from dumps and mine drainage was not appreciated as a major problem at that time. What was appreciated was that stream sediment sampling appeared to be a completely new approach to primary prospecting of virgin areas that might lead to spectacular discoveries".

This latter statement is somewhat surprising as Russian geochemists had demonstrated the effectiveness of heavy mineral[1] surveys using stream sediments (Fersman 1939), but perhaps at the time, 1947-48, the USGS translation had not been completed.

Hawkes' own work in Tennessee undertaken in December 1947 (Hawkes & Lakin, 1949) focused on residual clay

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[1] 'shlikh' in Russian.

Why minus 80 mesh?… *continued from page 1*

soils associated with zinc deposits. No details are provided concerning sample preparation, only a statement that samples were taken with a soil auger "consisting of three or four small fragments of clay weighing in all about 5 grams". Lakin *et al.* (1949) report "Pulverize this small sub-sample in an agate or mullite mortar to an impalpable powder and take a sample for analysis". So this work involved no particular size fraction, it was pulverized 'whole soil', and that soil was dominantly clay.

The work that Lovering *et al.* (1950) undertook in winter 1947-48 in Pinal County, Arizona, involved the sampling of soil and stream alluvium, sieve analysis, and the subsequent analysis of the sieve fractions. Samples "were taken and separated into fractions representing coarse fragments (2.0 to 0.208 mm, +80 mesh) coarse fragments ground fine, and fine fragments (less than 0.208 mm)". It should be noted that 0.208 mm is the largest particle size to pass [diagonally] through a 180 µm wire cloth sieve, i.e. 80 mesh (Table 10-13, p. 987; CRC 1972). The authors report, "The use of the fine fractions for sampling has two advantages: it concentrates the copper content and avoids grinding", and "In the routine sampling only the fraction less than 80 mesh in diameter was collected". Lovering *et al.* (1950) concluded "The most favourable geochemical approach appears to be studies of the copper dispersion in soils and alluvium. Samples of alluvium more than one mile downstream from the outcrop show a significant copper anomaly. The dispersion can be traced most easily by sampling only the fine fraction, because the copper tends to concentrate in the silt and clay fraction".

Subsequent papers by USGS geochemists report using the minus 80 mesh fraction for their studies, e.g., Canney *et al.* (1953) – for Co in 1953; and, Kennedy (1952) – for Pb, Zn in 1948-50. More importantly, analytical method papers were of great importance in spreading the geochemical prospecting methodology and the use of the minus 80 mesh fine fraction. Huff (1951) stated "The writer has used the following two procedures for sample preparation: A. Collect 100 to 500 grams of the material, dry, and sieve through a stainless-steel sieve with 2.0-mm openings. Crush fines in an iron mortar to a powder. B. Collect 100 to 500 grams of the material, dry, sieve through a stainless-steel with 0.2-mm openings (80-mesh sieve). Do not crush. Two possible alternatives are suggested for the method of measuring the amount of sample to be digested. Weighing the sample is accurate but is not as quick as measuring with a volumetric scoop. The writer usually uses a scoop having a capacity of 0.25 cu cm that is made by drilling a small cavity, which will hold about ⅓ gram of soil, in a plastic bar". A similar measurement procedure is described by Bloom (1955) "Lucite scoop. A Lucite bar, about ½ in by ⅜ in by 3 in, drilled at one end to contain about 0.1 g of minus 80 mesh soil".

Lakin *et al.* (1952) refer to the Hawkes & Lakin (1949) paper and the use of ground 'whole soil', and the Lovering *et al.* (1950) paper and their use of the minus 80 mesh fine fraction, and the requirement for 2 mm and 80 mesh sieves. Summarizing USGS work, Hawkes (1957) stated "The size fraction of the soil [or sediment] used for analysis may make some difference in the significance of the data. In some problems it has been found that the metal content of the fine fraction was somewhat, but not greatly, higher than the coarse fraction. In other experiments no significant variation with size was apparent. The standard procedure for Geological Survey work has been to collect the fines (minus 80 mesh) for analysis and discard the coarse fraction. This avoids the need of grinding the sample before analysis and may cut down erratic data resulting from possible coarse fragments of oxidized ore minerals such as lead carbonate and malachite. An alternative procedure is to collect all sizes less than 2 mm in diameter and grind before analysis. This procedure may be preferable where the soil lacks an appreciable proportion of fines or where the ore metal is concentrated in the coarser sizes".

From the foregoing it is suggested that minus 80 mesh was introduced by Tom Lovering in his soil and stream sediment orientation survey undertaken in the winter of 1947-48 in Arizona (Lovering *et al.* 1950). The analytical procedure used by Hy Almond (the analyst in the Lovering-Huff-Almond team) to determine Cu in the soils and alluvium was from soil science (Holmes 1945) and called for the analysis of minus 100 mesh (<0.15 mm) material ground from the less than 2 mm fraction of the soil. Perhaps, in discussion between the three colleagues, Lovering, Huff and Almond, it was Almond who suggested that the minus 80 mesh fraction would provide sufficiently homogeneous material for analysis. As previously noted, the largest particle that will pass through an 80 mesh sieve is 0.208 mm, and 0.208 mm is close to an order of magnitude less than 2 mm. Perhaps it was this logic that caused them to take a Tyler[2] 80 mesh screen to the field and investigate the less than 0.2 mm fraction. They found it effective and easily implemented without the need for grinding – and as they say, 'the rest is history'.

In early 1952, John Webb travelled to the U.S. and Canada and with Herb Hawkes they undertook a six week tour of commercial and academic geochemical exploration projects. They also visited Harry Warren and Robert Delavault at the University of British Columbia (Hawkes 1976; Howarth 2010). This visit was the beginning of a long association that led to the publication of the classic geochemistry textbook 'Geochemistry in Mineral Exploration' written by Hawkes & Webb in 1962. When Webb returned to Imperial College in London, he prepared a report on this visit (Webb 1953) that was delivered orally at the Institution of Mining and Metallurgy in December. There he stated "The dry sample is sieved and tests have shown that the minus 80 mesh fraction is generally satisfactory". Brotzen *et al.* (1967) reported "A geochemical prospecting course by J.S. Webb and H.W. Lakin at Imperial College, London, in 1953, and the Oslo conference in 1953

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[2] The Tyler (1910) 80-mesh screen has a nominal opening of 0.175mm, the ASTM (1961) 80 mesh has a nominal 0.177 mm opening. The nearest BSS (410/1969) sieve is 85 mesh with a nominal opening of 0.180 mm. In practice, any of these sieves would prove adequate and may be considered equivalent

Why minus 80 mesh?… *continued from page 5*

of the OEEC [Organization for European Economic Cooperation] Technical Assistance Project 144 (Webb & Lakin) were events that greatly influenced the acceleration and development of geochemical prospecting in Fennoscandia. Their influence was probably most conspicuous in Norway, where at the time, the application of geochemical prospecting was less advanced than in Finland and Sweden". And so the wheel turned, it was from Sweden that knowledge of the potential of geochemical prospecting, dominantly biogeochemical surveys, had first spread to North America through Nils Brundin and Hans Lundberg in the 1930s and kindled interest there.

The work of John Webb and his students in Africa carried the analytical methods and use of the minus 80 mesh fraction developed by the USGS to that continent, where quite possibly "It was the only size of bolting[3] cloth they could get from Johannesburg". Concerning the validation of the selection of the minus 80 mesh fraction by soil and stream sediment orientation surveys, Lovering's work is the first example. The highly successful prospecting campaign undertaken by Hawkes *et al.* (1960) in New Brunswick and Québec, Canada in 1954 and 1955 using the Bloom (1955) test for exchangeable heavy metals was another, where "… after drying, the samples were passed though a non-contaminating sieve, the coarse fraction discarded, and the fines [presumably minus 80 mesh] placed in a properly numbered coin envelope pending analysis", where a scoop was used to measure an aliquot for analysis. Orientation work was limited to determining dispersion train lengths, work around known mines and prospects demonstrating dispersion trains several miles long, and "… it was arbitrarily assumed that a given sample would not fail to indicate the presence of a base-metal deposit in the drainage basin if that deposit occurred within two miles of the sample site". It was this work that led to the recognition of areas of low and high geochemical relief, with the latter being associated with base-metal mineral potential. This in turn greatly promoted the execution of reconnaissance regional geochemical surveys, often using the Bloom test in the field to guide exploration. This was the author's introduction to the art and science of geochemical prospecting in Cape Breton Island, Nova Scotia, as a summer field assistant in 1962.

Subsequently, several studies in Africa were undertaken by John Webb's Geochemical Prospecting Research Centre (GPRC), later to become the Applied Geochemical Research Group (AGRG). The hypothesis was, where chemical weathering had occurred in these residual soil terrains, together with comminution in stream channels, the fine fraction would contain sufficient material derived from mineralization to be useful for exploration. However, some mineral occurrences composed of resistate minerals, may, on weathering, not yield fine fraction materials; those minerals may be in the coarse fraction of soils and sediments, due to the mineralogy of the occurrence. For example, James (1957) studying chromite deposits associated with the Great Dyke (Zimbabwe) investigated the Cr content of fractions yielded by 20, 36, 80, 135 and 200 mesh sieves. He found that Cr levels were highest in the minus 80 plus 200 mesh fraction, reflecting the size of the chromite crystals in the chromite seams when sampling 12 inches below surface. He concluded that "For most of the work, however, the -80 mesh (minus 0.2 mm) was to be entirely satisfactory", and that "-80 mesh is a practical exploration procedure".

Webb (1958) reported in 1956 on studies in Africa, mostly using the minus 80 mesh fraction. Also included were studies of Pb in soil by depth and size fraction in South Africa, for Cu in Ugandan stream sediments in the minus 80 and 200 mesh fractions, and for total and cold extractable Cu in Ugandan and Zambian stream sediments together with contrasts. He concluded that favourable contrasts exist in the minus 80 mesh fraction, and it is practical in requiring only a single screen preparation.

Debnam & Webb (1960) undertook studies of Be in various size fractions in soils and sediments around pegmatites in Uganda and Zambia. They found maximum levels in soils at 0-3, 12-18 and 24-36 inches and in fractions finer than 0.107 mm. Higher concentrations in surface soils were due to the removal of finer-lighter material by wind and rain. In the minus 80 mesh fraction of stream sediments, dispersion trains were >5 miles with a contrast of >10. They concluded, "… for all practical purposes analyzing the -80-mesh fraction permits the detection of longer dispersion trains than is possible when coarser fractions are examined."

Watts (1960) studied the dispersion of Nb as pyrochlore in soils and stream sediments derived from carbonatites in the Namwala Concession area of Zambia (Webb et al. 1964). The less than 20 mesh (1.075 mm) fractions of soils and stream sediments were further fractionated with 28, 82, 125 and 200 (0.076 mm) mesh sieves and the silt (<0.02 mm) and clay (<0.002 mm) fractions recovered. In soils, pyrochlore and Nb are enriched in surface layers by the preferential leaching and elutriation of the soluble and lighter components of the parent carbonatites, maximizing in the fine sand fraction, which was also reflected in the minus 80 mesh fraction. In stream sediments, proximity to a source of pyrochlore was indicated by a relative increase in the proportion of Nb present in the minus 20 plus 200 mesh fraction relative to the minus 200 mesh fraction, and that anomalies related to a significant deposit should be detected by analyzing the minus 80 mesh fraction of samples collected one mile apart.

Webb *et al.* (1964) report on an eastern Canada orientation survey at a regional scale. They note, "During the course of an extensive geochemical mineral reconnaissance carried out in New Brunswick in 1954 (Hawkes *et al.* 1956), broad-scale patterns were observed in the base metal content of stream sediments that appeared to be related to the distribution of the major geological units. As distinct from the local, highly anomalous values related to mineralization,

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[3] Bolting cloth is a firm fabric, originally woven of silk, used in the production of flour in the food industry. Now more often manufactured out of nylon.

Why minus 80 mesh?... *continued from page 6*

these patterns were developed merely as minor variations in the level and homogeneity of the background values associated with essentially unmineralized rocks. This observation suggested that multi-metal analysis of stream sediment samples might serve as a basis for compiling regional geochemical maps showing the distribution of the minor elements in relation, not only to mineralization, but to bedrock geology as a whole". In 1957 in southern Zambia, Selection Trust (Namwala Concessions Ltd.) had collected a suite of stream sediment samples, retaining the minus 80 mesh fraction for analysis for Cu, Zn and Ni. However, this work did not identify any economically significant mineral resources, but did "indicate a possible relationship with the bedrock geology". These samples were made available to the GPRC and they were re-sampled to generate a network of low-order stream samples at a density of one site per square mile over the 3,000 square mile (7770 km^2) of the study area. These were analysed by semi-quantitative DC-arc spectroscopy for 17 elements along with Zn and cold extractable Cu by colorimetry.

The authors reported:

1. The major geological units are associated with broad-scale patterns of variation in the range and mean concentration levels of several metals, notably, Pb, Zn, Cu, Cx Cu, Ni, Cr, V, Mn and, to a lesser extent, Co and Ti. The patterns are evident in both mineralized and barren formations.
2. In ground underlain by the unmineralized formations, the patterns mostly appear as variations in the level and range of normal background values, and are related to the lithology and composition of the bedrock.
3. In addition to the extensive patterns associated with the major geological units, smaller-scale patterns are also developed in stream sediments draining individual formations and rocks of similar lithology.
4. Despite the generally weak nature of the mineralization, the more strongly mineralized rocks are associated with more or less extensive patterns of abnormally high metal content.

The above studies confirmed the general utility of the minus 80 mesh fraction, and subsequently it was broadly adopted by the geochemical exploration community. Plant et al. (1988) reported on 39 recent regional geochemical surveys covering in excess of 5,000 km^2; of these, 23 (59%) employed the minus 80 mesh fraction. Two surveys used the minus 60, 10 surveys used fractions finer than 80 mesh (half of which were finer than 100 mesh), two organic materials, and two were unspecified. Where the minus 80 mesh fraction has not been used there have often been special considerations, such as desert terrain and the presence of fine wind-blown material, mountainous environments with high stream flow rates, and seasonal variation considerations related to monsoonal climates.

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CONCLUSIONS

1. Use of the minus 80 mesh fraction was first proposed by Lovering et al. (1950) of the USGS based on field work around copper occurrences in Arizona in the winter of 1946-47, and was quickly adopted by their colleagues;
2. The widespread adoption of the minus 80 mesh fraction was facilitated by the publication of papers on analytical methods developed by USGS chemists-geochemists specifying the use of that fraction, such as Lakin et al. (1949, 1952), Huff (1951), Bloom & Crowe (1953) and Bloom (1955). These papers, frequently published in Economic Geology, were widely read by mineral explorers around the world; and,
3. Orientation surveys, other than the work of Lovering *et al.* were *post-hoc*, studies involving the minus 80 mesh and other fractions. These confirmed the general applicability of the minus 80 mesh fraction as the fraction of choice for both soils and stream sediments in both detailed and regional reconnaissance surveys.

In light of the last conclusion, a final note is offered:

The art and science of exploration geochemistry requires that methods, i.e. the combination of material, size and possibly

Why minus 80 mesh?... *continued from page 8*

mineralogical fraction, and analytical procedures, that maximize the contrast between background and anomaly be developed and used.

Over the last 70 years the use of the minus 80 mesh fraction for soil and stream sediment analysis has proven effective and led to the successful discovery of primarily base metal mineral resources. However, that does not mean the use of the minus 80 mesh should be taken for granted, as directed orientation work may indicate a more suitable size fraction for specific trace elements and mineralogical conditions, in particular precious metals.

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Why minus 80 mesh?... *continued from page 9*

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