Morphology of placer gold grains as a predictive tool in placer and primary source exploration

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Morphological changes to gold particles during fluvial transport occur in response to interaction with other sedimentary particles and/or the substrate. The changes are a function of transport distance and reflect changes in fluvial gradient, bed roughness, turbulence, velocity, and bed load in the river. Particle size, outline (2-D), shape (3-D), and texture are all modified by abrasion, flattening, folding, and breakage during transport. Resultant morphological characteristics can be used to predict transport distance, source type (primary/palaeoplacer), and source location, as well as the origin and dispersal patterns of gold in palaeoplacers remnants where transport history is unclear.

In physical-weathering regimes, gold commonly enters fluvial systems as inclusions within relatively easily transported ore clasts. Maximum particle size may increase for the first few kilometres downstream from the entry point(s) as ore clasts are comminuted and gold is released; however, further downstream the particle size progressively decreases. Conversely, in chemical-weathering regimes, gold typically enters fluvial systems as free particles; maximum particle size occurs near the entry point(s) and decreases progressively downstream.

In the moderate-to-high-gradient (upper reach) catchments, a moderate amount of particle rounding occurs and is focussed initially on grain extremities and protrusions between grain re-entrants. Brittle inclusions of gangue material are typically removed in such reaches but cavities from which inclusions were 'plucked' are commonly preserved into the transition zone to more typical trunk river gradients downstream, albeit with some smearing or abrasion of adjacent surfaces. Thus, the texture of gold particles in proximal reaches changes from pristine surfaces between inclusions (if present), to rounded and abraded protrusions between inclusions or cavities from which they were plucked, to more rounded, abraded, and smeared particle surfaces with relict cavities plus or minus remnant inclusions.

Preservation of 'pluck-cavities' into the transition zone between proximal (tributary) and more typical trunk river gradients indicates that little or no flattening, folding, or breakage of gold particles occurs in the proximal reaches. The Flatness Index [F.I. = $(a+b)/2c$] of gold particles upstream of the transition typically ranges from c.1 to 10 and reflects flatness inherited from primary source(s) rather than particle flattening during transport. Flattening, folding, and breakage of gold particles increases markedly through the transition zone and middle reaches of the trunk river. Flatness Index maxima (F.I. up to c.30), roundness, and the proportion of folded particles all increase and remaining inclusions and cavities from which they were plucked are effectively eliminated. Flattened-discoid-, cylindrical, and folded particles become more common, and surface textures become progressively more smoothed as the grain size of the associated fluvial sediment decreases. Distal trunk placer gold has a relatively high Flatness Index (F.I. up to 40), is typically well rounded and smoothed, and is dominated by discoid and cylindrical particles, up to 50% of which may be folded or multiply folded.

The Flatness Index of gold particles, the proportion of folded particles, and particle roundness in a given sample are useful indicators of source type (primary/palaeoplacer/till), additional gold inputs along the transport route, and fluvial transport distance. A reliable and predictable relationship between F.I. maxima and fluvial transport distance defines a critical F.I., above which gold is entrained and transported, and below which it is incorporated into a placer. Particle F.I. is increased by flattening, but is decreased by breakage and especially so by folding. Gold particles entering a system with subcritical F.I. must be flattened to supercritical F.I. before further transport can occur.

The relationships between maximum F.I. maxima, mean F.I., and particle folding can distinguish first-cycle, multi-cycle, and multi-source placers. F.I. maxima relate to downstream changes in fluvial dynamics in the last transport cycle, whereas F.I. mean is sensitive to additional gold inputs en route and particle folding. Mean F.I. can be markedly decreased by local inputs from relatively proximal placer, palaeoplacer, or primary sources, but can be increased by incorporation of gold recycled from relatively distal placer or palaeoplacer sources. Flattened and/or folded particles in moderate-to-high gradient tributary valleys generally indicate a more distal palaeoplacer source rather than a primary source. Abundant non-folded gold with subcritical F.I. in trunk placers typically indicates local primary and/or relatively proximal palaeoplacer sources en route.