

# THE TRACE ELEMENT GEOCHEMISTRY OF VEIN MATERIAL IN EPITHERMAL SYSTEMS: SIGNIFICANCE FOR EXPLORATION

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## ABSTRACT

Vein samples from the exploration for epithermal mineralisation are commonly subjected to multi-element analysis. Trace element geochemical response in such material is a recognisable characteristic of epithermal mineralisation, and provides a routine "fingerprinting" method. In this role, however, vein geochemistry should only complement, not be a substitute for, morphologic and textural observations. Vein geochemistry is not convincing as an indicator of vertical zonation within a mineralised structure; alteration and fluid inclusion studies are more useful in such assessments.

## ROUTINE MULTI-ELEMENT ANALYSIS OF VEINS

It is obviously good practise, when exploring for epithermal gold mineralisation at any scale, to sample any vein material encountered and assay for gold and other "ore" elements of interest. It has also become common to analyse such samples for a range of trace elements. This serves any one of a number of purposes:

1. to confirm that any gold mineralisation in a recognised lode structure is epithermal in origin, i.e. the trace element response of the lode sample is characteristic of epithermal mineralisation;
2. to indicate whether a vein, not recognisably within a lode structure, is proximal or distal from such a structure within an epithermal system, i.e. indicates the position of the vein relative to any lateral geochemical zonation of the mineralising system;
3. to deduce the relative position of the sample with respect to the main zone of gold mineralisation in a recognised lode structure, i.e. the position of the lode sample relative to vertical geochemical zonation of the mineralised structure;
4. as an orientation for the planning of secondary media (soils, stream sediments, botany) exploration geochemistry programmes, i.e. to predict the secondary media geochemical response to mineralisation;

This paper will examine in turn the theoretical/empirical basis for these uses (except the last) and discuss their validity in application.

## EPITHERMAL TRACE ELEMENT RESPONSE

### The theory

Surprisingly, there are few published data on the trace element composition of vein material from epithermal gold deposits. Commonly, only the vein mineralogy is reported for these deposits, and is used to infer the corresponding geochemical response (it can be safely assumed that where tellurides, for example, are generally present in veins, Te is a geochemical component of the vein).

Even so, it has been long recognised that epithermal deposits in western North America tend to contain a common suite of "ore" elements; Au, Ag, As, Sb, Hg, Tl, W (Fig. 1; Berger and Eimon, 1983). Other minor elements that may be significant are Cu, Pb, Zn, Mo, Te, Ba and F. The geochemical signatures of epithermal deposits in the southwest Pacific region are similar (Clarke and Govett, 1988). This suite of elements are also concentrated by active geothermal systems, which supports the genetic link between such systems and epithermal deposits (White, 1981).

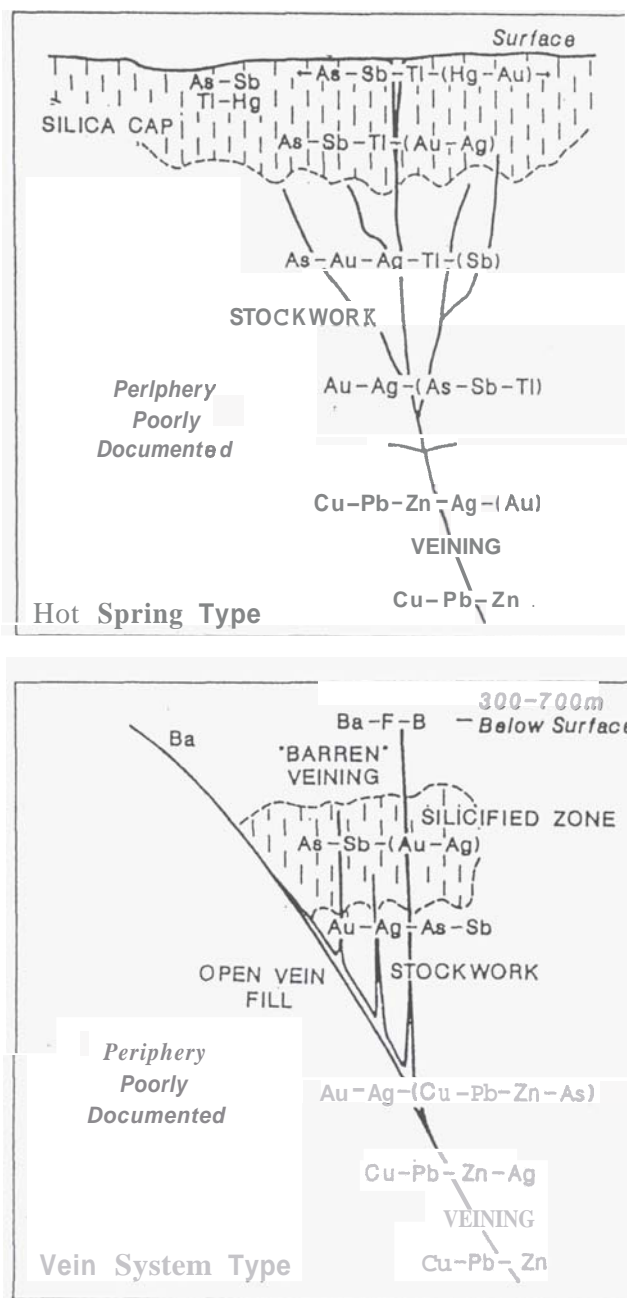


Fig. 1: Schematic cross-sections for epithermal deposit models showing structural features and characteristic minor element response (after Berger and Eimon, 1983; Clarke and Govett, in press). Vertical scale of systems - hundreds of metres; lateral scale - tens of metres.

Clarke

The application

Evaluating the geochemical response of vein samples generally involves an empirical comparison with the corresponding response from known epithermal deposits. There is, however, difficulty in collating the data from existing studies; whether an element is reported as being "enriched" or "significant" in vein material from a given deposit is influenced by:

- whether that element was analysed for during the investigation,
- the detection limits of the analytical method used,
- the relative contents of other elements present (e.g., a vein with 200ppm Cu and 20000ppm Zn might be reported as only having high Zn values whereas both elements might be considered enriched in a vein with 200ppm Cu and 200ppm Zn),
- the subjective judgement of the observer. There exists no benchmark, such as a collation of epithermal and non-epithermal quartz analyses, against which a systematic evaluation of vein results can be made.

In spite of these concerns, vein geochemistry response as a characteristic of epithermal deposits (as proposed by Lindgren, 1933) does appear to hold true. An example of "fingerprinting" epithermal vein material -- analytical results of selected elements for a vein sample from the main mineralisation at the Umuna gold deposit (PNG) has been presented by Clarke et al. (in press). Along with the ore grade Au and Ag concentrations, the trace elements of interest (As 16ppm, Sb 6ppm) are present in the ppm range, and other "significant" minor elements are "high" (Zn 1500ppm, Ba 2400ppm).

## LATERAL ZONATION

The theory

Fracture and vein material forms areally extensive evidence of a fossil hydrothermal plumbing system; where this system is associated with epithermal mineralisation, it is likely that such material will carry the characteristic trace element response. Geochemical zonation patterns for fracture or vein material in peripheral areas have not been documented for epithermal gold deposits (fossil geothermal systems) or for active geothermal fields. It may be predicted that whereas the likely geochemical signature of a higher temperature regime (possibly, peak concentrations of Au-Zn-W-Mo) will be constrained to the central parts of the system, the more mobile elements (such as As-F-Ba) will still prevail in peripheral areas (Clarke and Govett, in press).

The application

The value of fracture sampling in exploration for epithermal lodes has not been reported in the literature, but there are numerous examples for other types of deposits. The Carlin-type Cortez gold deposit in Nevada was discovered by following up regional scale As, Sb, and W anomalies in samples of fracture fillings and jasperoid in limestone (Erickson et al., 1964). At the prospect scale, Crone et al. (1984) analyzed Fe-oxide coatings from fractures around the Pinson Mine, Nevada; they found that As and Sb anomalies extended over more than 1km in the fracture coatings.

The Upper Edie Creek epithermal vein deposits in the Morobe Goldfield of Papua New Guinea has been the target for a well documented investigation of vein geochemistry in the vicinity of major lode mineralisation (Lowenstein, 1982). Precious metals and sulphides are hosted in quartz, calcite and manganocalcite beneath strong near surface oxidation. Variations in the geochemistry of the known epithermal mineralisation were examined in an attempt to recognize economic extensions and new deposits.

Nearly all oxidized surface expressions of mineralisation (quartz-manganese material) at Upper Edie Creek were sampled. This work led to the recognition of barren and mineralized stringers (veins). These were considered virtually indistinguishable in the field, other than that the Au-rich stringer are confined to close proximity to the major lodes in distinct northeast trending fracture zones, whereas the barren stringers are variably oriented over a large area extending out over 1.2km from the major lodes. The mineralized lodes were also found to be characterized by high Au, Ag, Sb, Mn, Fe, Pb, As and the barren lodes by high Ba and As.

Lowenstein (1982) concluded, therefore, that As (and Ba) were not good pathfinders to ore, as it was associated with both Au-rich and Au-poor veining in the district. An alternative conclusion is that Ba and As are, in fact, excellent regional pathfinders at Upper Edie Creek. Assuming all the veining at Upper Edie Creek was the

result of one event, these elements may thus better reflect the actions of an ore forming hydrothermal system, over an area more extensive, than that indicated by Au mineralisation.

## VERTICAL ZONATION

The theory

The vertical zonation of ore and trace elements within the mineralizing structure of North American epithermal deposits is widely accepted (Berger and Eimon, 1983; Silberman and Berger, 1985), as illustrated for the Hot Spring (near surface deposition) and Bonanza Vein (deeper deposition) deposit types in Fig. 1. Cu, Zn, Pb, Ag tend to be most elevated deeper in the systems, with Au, Ag, Ti and As present in high concentrations in the mineralized zone. As and Sb are more prominent higher in the system. Te and V are associated with high Au values in some deposits (Cox and Bagby, 1986). The sinter zone of the Hot Spring type deposit can be marked by high concentrations of Sb, Ti, Hg, whereas the upper parts of the Vein type system may be enriched in Ba, As and F (Berger and Eimon, 1983).

Element enrichments and their vertical zonation in the vein and breccia material of Philippines epithermal gold deposits is similar to that presented for North American examples (Celenk and Lazo, 1988). In the shallow acid alteration zones of deposits having little last alteration, the assemblage S-As-Tl-(Hg-Sb-Pb) is characteristic. In all parts of a system beneath this acid alteration zone Au-Ag-As-Sb-Bi-Te-Mo-Se-Hg-Tl are important. Cu-Pb-Zn-Cd are significant deeper in the system, whereas Hg-Tl-Se decrease with depth.

The application

Vertical zonation is a common characteristic of metal distribution in epithermal gold deposits, and major precious metal mineralisation may only occur over a small vertical interval (e.g., Berger and Eimon, 1983; Buchanan, 1981). Thus, once the depositional zone in an epithermal system is identified it is necessary to deduce at what level in the system the zone occurs (i.e., where the erosional surface is now with respect to the paleo-surface or paleo-water table). Pathfinder element concentrations in vein material are commonly considered when confronted with a problem of level of exposure.

Use of this feature is limited, however, because it is likely that all these elements can deposit in all parts of the lode system; the zonation does not imply the exclusive deposition of any particular element at a given level but only indicates relative abundances. The use of terms such as "higher contents" and "elevated contents" are relative (as with most geochemical modelling), and a single analysis from one level in a vein system will not allow an unambiguous conclusion. Morphology, vein textures and alteration patterns are probably more useful (e.g., sinter and acidic-alunite alteration above hot spring deposits) and fluid inclusion studies represent an important technique.

When comparing two levels of veining to ascertain vertical zonation, it is (obviously) necessary that the vein material being compared originates from the same epithermal system. This constraint has important ramifications where a vein system with elevated As, Ba and/or F but "no" precious metals is recognised in proximity to a mineralised vein system.

This has been the case in the Morobe Goldfield as described above. An interpretation presented above has the "barren" veining as a good lateral indicator of the proximity of mineralisation, with all veining the result of one epithermal event. It might alternatively (but much less confidently in this case) be interpreted that the random Ba-As-rich barren stringers are parts of orebodies exposed at a relatively higher level in a different system than the more structurally controlled Au-Ag-Sb-rich mineralized lodes (Clarke and Govett, in press); one system overprinting the other.

## PREDICTING SECONDARY MEDIA GEOCHEMISTRY

The theory

The geochemical signature for epithermal vein material will be retained when that material is dispersed into the secondary media (soils, stream sediments, plants). Thus an understanding of primary trace element geochemical patterns for known mineralisation are important to the design of appropriate drainage, soil or biogeochemical surveys in nearby areas.

## The application

Empirical orientation studies on known mineralisation are relatively straightforward, but it is important to recognize that vein material is not the only media with a strong geochemical response in epithermal deposits. Also of major importance to modelling soil surveys is an awareness of the probable extent of host-rock geochemical signatures around mineralisation, as an alternative to potential dispersion from vein material (Clarke and Govett, in press). These host-rock halos should be reflected in overlying in situ soils to form similarly extensive targets for exploration, and also contribute to stream sediment geochemistry.

Geochemical models for the exploration of epithermal gold deposits, based on simplistic application of generalised characteristics, is commonly applied too rigidly. In a recent formulation of such a model by soil geochemistry, Hoffman (1988) indicated that a coincident Au and base metal anomaly should rate below a Au-only anomaly as a priority for evaluation. This conclusion was made by taking into account the vertical zonation attributed to epithermal deposits; a base metal anomaly at surface is deemed to indicate that the present erosional level is below the main zone of Au deposition. There are a number of geochemical features of these deposit which were not considered.

Firstly, the above model does not allow for overlapping of the components in this zonation; in many deposits base metals are distributed throughout lode material, even if they tend to concentrate in the deeper levels below maximum gold deposition. Also the model does not recognize that high contents of the base metals occur in the wallrock to the lode material. Geochemical responses in wallrock are likely to be even less strongly controlled by elevation than are such responses in lode material.

## CONCLUSIONS

Trace element geochemical response in vein material is certainly a recognisable characteristic of epithermal mineralisation, and provides a routine "fingerprinting" method. The permutations possible in vein material geochemistry are, however, poorly understood; vein geochemistry should only complement, not be a substitute for, morphologic and textural observations. Host-rock trace element geochemistry needs to also be considered when searching for areally extensive indicators of mineralisation. As an indicator of vertical zonation of metals distribution within a mineralised structure, vein geochemistry is not convincing; it is here that alteration and fluid inclusion studies are more useful.

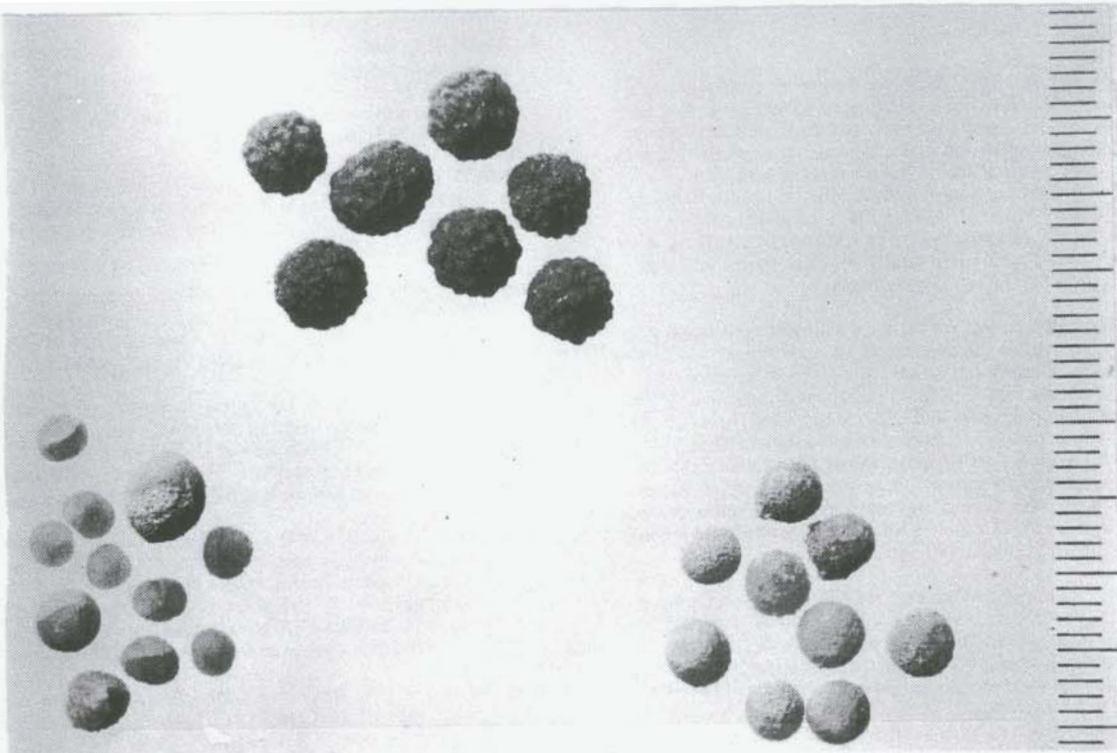
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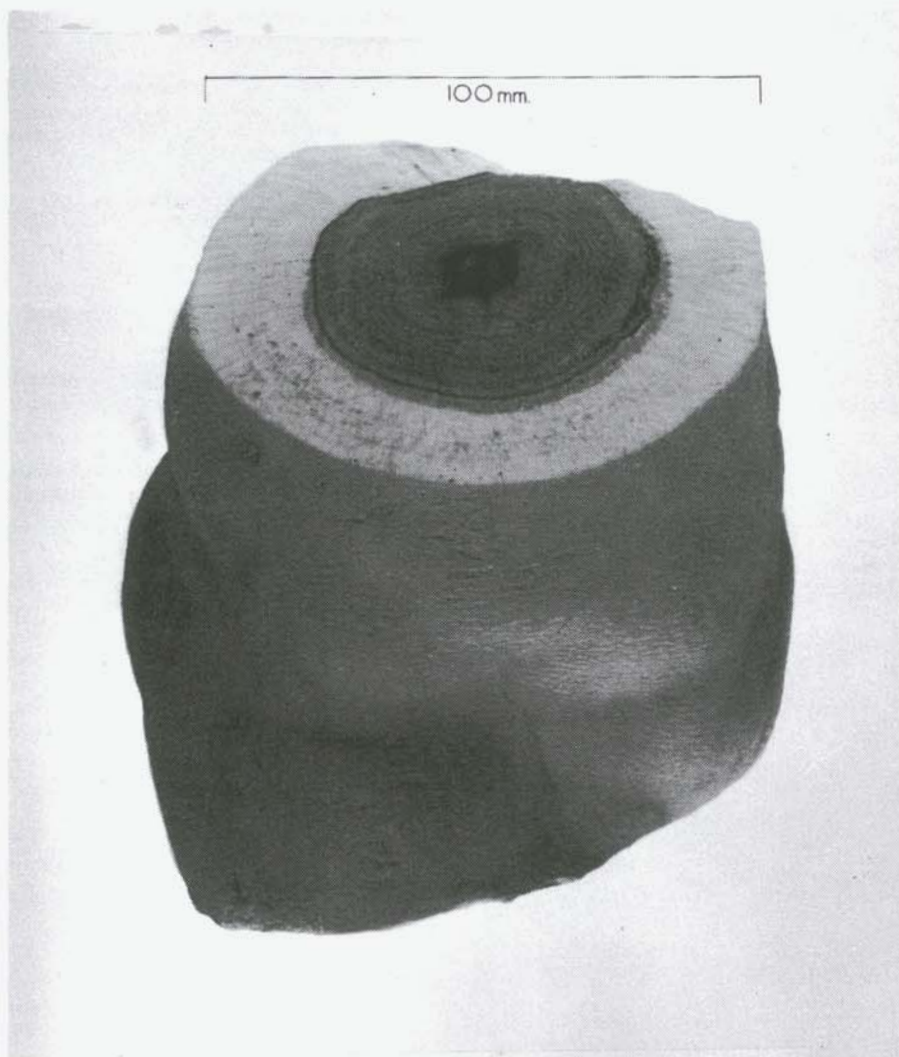
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SILICA BALLS FROM SILENCER DEPOSITS Ka 3 (TOP), Br 3 (LOWER LEFT) AND Br22. SCALE IN mm. Photo: D. L. Homer, NZ Geological Survey.



ARAGONITE DEPOSITED ON BLACKBERRY STEM. DISCHARGE FROM Br6, 1972. Photo: D. L. Homer, NZ Geological Survey.