

GOLD '86 — An International Symposium on the Geology of Gold Deposits

James W. Stewart, A. C. Colvine, J. M. Franklin et J. P. N. Badham

Volume 14, numéro 1, mars 1987

URI : https://id.erudit.org/iderudit/geocan14_1con01

[Aller au sommaire du numéro](#)

Éditeur(s)

The Geological Association of Canada

ISSN

0315-0941 (imprimé)

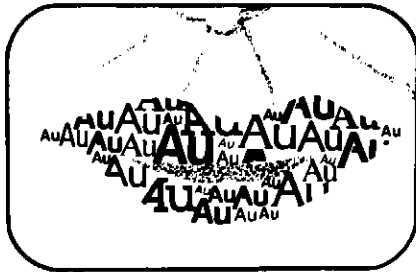
1911-4850 (numérique)

[Découvrir la revue](#)

Citer cet article

Stewart, J. W., Colvine, A. C., Franklin, J. M. & Badham, J. P. N. (1987). GOLD '86 — An International Symposium on the Geology of Gold Deposits. *Geoscience Canada*, 14(1), 53–57.

Conference Reports



GOLD'86 — An International Symposium on the Geology of Gold Deposits

James W. Stewart
*BP Resources (Canada) Limited
 Selco Division
 55 University Avenue, Suite 1700
 Toronto, Ontario M5J 2H7*

A.C. Colvine
*Ministry of Northern Development and
 Mines
 Ontario Geological Survey
 77 Grenville Street
 Toronto, Ontario M7A 1W4*

J.M. Franklin
*Geological Survey of Canada
 601 Booth Street
 Ottawa, Ontario K1A 0E8*

J.P.N. Badham
*BP Minerals International Ltd.
 4 The Broadway
 Newbury, Berkshire RG13 1BA England*

Introduction

(J.W. Stewart - Program Chairman)

GOLD'86, An International Symposium on the Geology of Gold Deposits was held in Toronto from 28 September to 1 October 1986. The event was organized by the Toronto mineral exploration community and was sponsored by the following organizations: the Mineral Deposits Division of the Geological Association of Canada; Ontario Geological Survey, Mines and Minerals Division, Ministry of Northern Development and Mines; the Society of Economic Geologists and the Toronto Geological Discussion Group.

The stated purpose of the Symposium was to provide a forum for discussion of gold deposits discovered around the world in recent years; the Hemlo deposits were marked for special attention. The Symposium was attended by over 1400 delegates from 34 countries.

Authors were advised to provide a factual account of the geological setting and mineralization of each gold deposit discussed, integrating this information with laboratory data: provision of a genetic model was encouraged.

Of 128 papers submitted to the Program Committee, 36 were selected for presentation at the technical sessions and a further two papers were held in reserve. Each of the 38 papers was reviewed by two independent authorities and all appear in the Proceedings Volume of GOLD'86 (see end of report) which was published in time for distribution at the Symposium. (The volume is about to go into second printing).

At the end of each day's technical program an invited speaker summed up the papers presented in the morning and afternoon sessions to help the audience appreciate the wider implications of the new information being presented and identify changing metallogenic concepts which became apparent as the Symposium progressed. Some weeks prior to GOLD'86 the invited speakers were provided with texts of the papers which they were to sum up. They were also invited to provide a written version of their summary for publication.

The session categories were based on diverse and partly incompatible concepts (e.g. re-interpretation, new discoveries, defined regions, specific deposit types), which did nothing to ease the task of the summing up speakers. Nevertheless, as the following articles show, the speakers coped well with this difficulty. An inadvertent consequence of this conflicting category problem was omission from the summary process of Colin McKenzie's paper on the Chetwynd (Newfoundland) deposit.

Canadian Precambrian Deposits

(A.C. Colvine)

Day 1 of GOLD'86 set the standard for the meeting, with good to excellent presentations of broad interest while maintaining the deposit descriptive emphasis; as a result, it was "standing room only" in the 1250-seat theatre for most of the day. The papers consisted of a good spectrum, ranging from relatively preliminary progress reports to fairly comprehensive and complete studies; most speakers resisted the temptation to over-interpret their data.

The results of the day's session were remarkable in two respects; first, the apparent local differences between deposits seemed to be outweighed by features common between them; and, second, the unanimity as to the genetic model. This late, shear-controlled epigenetic model was in contrast to the diversity of models presented at the equivalent sessions at GOLD'82 in Zimbabwe, where many proposed an early, syngenetic component of gold concentration. Research is an evolutionary process, requiring time to apply careful scientific method, and GOLD'86 represented a progress report on that evolution.

There was a strong message in the common thread to all talks; careful field observation is both a powerful tool and a prerequisite for meaningful, more "sophisticated", research. Repeatedly, throughout the session, speakers were able to unravel the complex sequence of geological events which had affected host rocks since deposition or emplacement, and to clearly establish gold's position in the paragenetic sequence.

This approach also elucidated the real significance of some of the more commonly described attributes of deposits. For example, the conclusion that many are strata-bound and/or stratiform is common where interpretations can only be made from drill core and limited surface exposure. With better access and exposure and detailed mapping, Savoie, Melling and Workman all showed the "ore horizon" to cross-cut lithostratigraphic contacts at a low angle, and Marmont indicated the ore zone was at a relatively high angle to regional volcanic strike. Similarly, while gold is often hosted by chemical sediments, Hall and Wyman both

showed that its distribution was not consistent with its being a primary component of these sediments; they indicated that chemical sediments represented a favourable structural-chemical site for subsequent gold precipitation.

It was also clear that structural analysis is an important component of deposit description. Andrews and Hall elegantly demonstrated how progressive deformation created the permeabilities necessary to permit fluid flow and gold deposition. This also provided some predictability to ore body form, distribution and plunge as also shown by Melling and Savoie. Through recent underground access at Casa-Berardi, Pattison was able to show gold mineralization controlled by anastomosing shears, in contrast to the interpretation made from drill core in the Proceedings volume.

The "faults" or "breaks" long recognized as spatially associated with, but rarely hosting, deposits, as pointed out by Pattison and Savoie, were shown by many speakers to be a brittle, often late, component of broader ductile shear systems, which encompass most deposits. The regional extent of these shear systems, indicated by several speakers, present potentially favourable horizons, albeit structural horizons, for exploration.

Intense and extensive wallrock alteration was also an important characteristic described by most speakers. Much of this was described megascopically, and well defined petrographically and, to a lesser extent, geochemically. Not only does this provide a critical clue to the mineralizing process but it also potentially presents a bigger target than gold itself and a basis for area selection in exploration.

The rough symmetry of alteration about the deposit was shown by Melling, Mason, Spooner, Workman and others and that it was not restricted to stratigraphic hangingwall or footwall where stratigraphy could be defined. Carbonatization was commonly described to occur as a broad halo around deposits but Andrews demonstrated that carbonatization mostly preceded gold introduction but does not necessarily contain mineralization.

Despite some alteration assemblages common to many deposits there were also significant differences from deposit to deposit. It became clear that, while alteration is a good guide, an understanding of the systematics of the alteration process through comparative studies is necessary, before it can be more widely used as an exploration tool.

The role of metamorphism was also addressed by several speakers. There is a common belief that, because the rocks are very old and have been metamorphosed, the deposits themselves have also been metamorphosed. It became clear that both mineralogical and textural petrography analyses were necessary to address this topic. Andrews, Hall and Marmont all presented strong evidence that the principal hydrothermal alteration associated with gold mineralization was at least synchronous with, and possibly post-dated, attainment of peak

metamorphic conditions. These relationships are, however, most easily documented in amphibolite facies terrains.

Many speakers indicated a close spatial association with small- to medium-scale felsic to intermediate intrusions and several considered the possibility of a genetic relationship. Marmont showed evidence that mineralization was temporally close to emplacement; Savoie considered the possibility that fluids were derived from the adjacent Mooshla complex; Hall suggested that fluids might be directly related to albitite dyke emplacement; and Andrews was able to bracket mineralization as synchronous with late felsic intrusion, about 20 m.y. younger than cessation of volcanism.

The mighty McIntyre-Hollinger system was addressed in two talks and inevitably there was some divergence in interpretation. Mason considered it a porphyry system developed about the core Pearl Lake porphyry and that mineralization was deformed to the same extent as its host rocks by the enclosing shear system. Spooner showed mineralization cutting younger albitite dykes which may be related to a deeper magmatic event from which mineralizing fluids were derived; he considered mineralization to be late in shear zone development. The writer would not presume to pass judgement but would merely point out the many similarities between the two presentations. Both studies add to the McIntyre-Hollinger story.

There was sufficient agreement throughout the day that a reasonable consensus was achieved on several points: (1) the deposits were formed after lithification and some folding of their host supracrustals; (2) they are controlled on a local and possibly regional scale by shear systems which may themselves deform the deposit to some extent; (3) they are associated with intense and extensive wallrock alteration which is often roughly symmetrical about the deposits; (4) gold and associated alteration are temporally close to peak metamorphism; (5) there was no evidence presented for a local, protore source of gold.

At least two obvious questions remain to be resolved: (1) What is the source of the fluid? Is it related to devolatilization of the mantle, metamorphic de-watering in the crust, or to a magmatic event?; (2) What, if any, is the role of felsic intrusions? And which, if any, syn- to post-tectonic intrusions may be relevant?

The trend to careful descriptive geology will undoubtedly continue and structural analysis will be an important component; shear zones and mylonite are becoming popular again but they should be used as well defined and documented terms as part of a comprehensive description, and not merely used to replace other nebulous, "in vogue" terms.

Lastly, the comment by one of the participants after the session, "The ghost of Graton was in the back, cheering", seems most appropriate.

Other Precambrian Deposits (J.M. Franklin)

In the preceding section, A.C. Colvine noted the renewed emphasis on describing the structural control of gold deposits in the Canadian Shield, with the consequent determination that gold deposits formed relatively late in the tectonic history of most areas. The data to support the syngenetic hypothesis seem to be sparse. The principal debate revolved about the question of which (if any) magmatic system provided the mineralizing fluids. The papers describing gold deposits in other Precambrian shields and the Hemlo camp continued to provide more, descriptive information that largely supports the conclusions presented earlier at this symposium. However, some interesting contrasts, both in descriptive attributes and possible genetic models, emerged.

Several aspects of gold mineralization are possibly less commonly observed (or at least reported) in the Canadian Shield. For example, the alteration described by Clark *et al.* at the Victory Mine near Kambalda, Western Australia, is dominated by a large biotite-bearing envelope. Biotite has developed in response to progressive carbonatization of the pre-alteration amphibolite-grade metamorphic assemblage. Other alteration zones, including the progressive change in carbonate species from calcite to dolomite, can also be explained by an increasing mole fraction of CO₂ during alteration. Such zonation of alteration has practical value, as it can be used to provide a "vector" toward the gold-rich zones in a mineralized district. Chloritoid, as described by Thomson in the Crixas deposit of Brazil, is less commonly expected as an alteration mineral associated with gold deposits than it is with massive sulphide and iron deposits. In the latter deposits, chloritoid is the result of metamorphism of a peraluminous, sodium-depleted, carbonate-rich syn-volcanic alteration zone; Thomson has shown that chloritoid can also form in a gold zone. Examples of chloritoid alteration in Canadian gold deposits are mostly commonly associated with pyritic schist deposits (e.g. Thompson Bousquet), and not with vein-type deposits. The common characteristic is the depletion of sodium, a feature less common in most gold-bearing districts than in the alteration pipes to massive sulphide deposits.

Both the Victory mine and the deposits of the Northwestern mining camp in Zimbabwe have a wide variety of types of mineralization, a feature that is common to many deposits in the Canadian Shield as well. Both of these deposits have "replacement" mineralization in iron-rich rocks, and also vein-type mineralization. Many of these characteristics are typical of districts in Canada; the Camflo mine, for example, has abundant "disseminated" mineralization in a porphyritic intrusion, and localized, but very high-grade, gold in a "replacement" sulphide zone in iron formation; the Geraldton area has similar types of gold distribution.

The timing of mineralization seems to vary from district to district. Evidence obtained through careful petrographic study by Thomson at the Crixas mine indicates that the gold was emplaced after the peak of metamorphism. Hamilton, on similarly careful work, determined that the gold was possibly emplaced immediately prior to the peak of metamorphism in the giant Kolar field of India; he indicated that as an alternative, the alteration may have been formed from relatively high temperature fluids, thus initially forming a lower amphibolite assemblage of alteration minerals. The age of alteration relative to metamorphism can only be determined in rocks that are compositionally likely to have diagnostic minerals and textures. Altered mafic rocks and pelites offer these characteristics more commonly than felsic volcanic rocks or intrusions. Work of this nature has been done at Red Lake; more studies of this type should be done in compositionally appropriate areas.

This session was not without some difference of opinion, however. The two papers on the Ropes mine in northern Michigan provided contrasting interpretation, based on two different views of the nature of the host rocks. Bornhorst described the rocks as highly altered and tectonized, and called them "schists", but Brozdowski indicated that the schists are really not so deformed, and interpreted some textures as being of primary volcanic origin. It would appear that the origin of the rocks is most clear in areas slightly more distant from the gold zone. Could some of the fragments have a tectonic, rather than volcanic origin? Undulatory and polysutured quartz probably indicate that the rocks were indeed highly strained, and evaluation of primary features must be done in light of the obvious deformation history that has affected the area.

Based both on these presentations as well as the papers presented previously, several problems need further research, in my opinion, if we are to have a model for the genesis of gold deposits that can yield totally reliable exploration criteria. Some of these are: (1) the three-dimensional form and tectonic history of the major structures ("breaks" of the Abitibi belt) that are so commonly associated with gold-bearing areas; (2) constraints on the sources of the large amount of CO₂ that has been added to many areas of gold mineralization have not been discussed.

Structure: Many of the papers on Precambrian Shield deposits provided evidence that the major (in some areas, transcurrent) fault structures associated with many major gold districts are broad zones, typically multiple faults over widths of up to a kilometre, that consist of lensoid "tectonic slices". As Hamilton suggested for the Kolar area, some of these slices may have been transported tectonically for tens or even hundreds of kilometres. Where juxtaposed, these individual fault-bounded "slices" form a pseudo-

stratigraphy. The bounding faults are easily overlooked, particularly where they are narrow zones of ductile shear, and the stratigraphy within adjacent slices or panels may be interpreted erroneously as a continuously superposed sequence. These major faults resemble the "docking faults" bounding "suspect terranes" of the Cordilleran region. In the shield areas, the secondary structures associated with these major faults are more commonly zones of brittle, rather than ductile, failure, and contain the principal gold deposits. Interestingly, secondary structures associated with major tectonic sutures in British Columbia also contain sizable accumulations of gold; the Cinola deposit, on the Queen Charlotte Islands, is in the Sandspit fault, a secondary structure to the Queen Charlotte fault which is the zone of oblique subduction of the Explorer Plate under North America. In the Precambrian Shield areas, we understand very little of the nature of these major faults, particularly in their third dimension. Hopefully, deep-crustal seismic experiments such as those proposed by the Canadian Lithoprobe Project will determine their configuration at depth.

CO₂ problem: The abundant carbonate alteration common to many major gold districts has almost uniformly been shown to have been emplaced prior to the gold, but to postdate all but the latest (and usually gold-bearing) structures. The amount of CO₂ preserved in the rocks is commonly a function of the availability of suitable cation species to take it up. Thus mafic rocks, with higher abundances of Ca and Mg have more carbonate than nearby felsic rocks. The amount of carbonate thus preserved may be considerably less than that which actually passed through the altered zone. The trend expressed in several papers at this meeting is to call on a magmatic system as a source of the gold-bearing hydrothermal fluids; a fluid separated early from a felsic melt would have been light and very CO₂-rich. Such a fluid might have undergone phase separation into a very CO₂-rich vapour component and a relatively gold-rich liquid during its ascent; the former may have preceded the rising mineralizing fluid, and could have carbonatized the rocks in and adjacent to the major structures discussed above. Could all of the CO₂ required to carbonatize the host rocks be obtained from a magmatic system? Until the source magmas are identified, this cannot be ascertained. Determining the precise time of mineralization will be a critical aspect of solving this problem. For now, it would seem somewhat unlikely that the intrusions identified in many major districts are major sources of gold, but careful evaluation of mass balance considerations and isotopic data are required to quantify the data pertaining to magmatic *versus* metamorphic sources for the fluids. With the potentially very deep extent of the major faults, perhaps a mantle source for CO₂ should be considered!

Source of Gold: Many of us have dabbled in the calculations of adequate sources of gold. For example, all of the gold that has been mined or is in the reserve in the Timmins camp would require removal of 50% of the gold from about 1100 km³ of greenstone; such a high efficiency of removal may be impractical, requiring an even larger volume of source rock. Can such large source requirements be met by the proposed intrusions that generated the magmatic fluids as suggested earlier at this symposium? Not only is a rather large intrusion needed to generate a Timmins or Hemlo camp, but the fluid must be focussed along a rather well-defined structural zone that, in the cases of Timmins, Kirkland Lake and the Cadillac to Val D'Or areas, may extend for tens to hundreds of kilometres.

Isotopic data have been called on to constrain the sources of fluids, but with limited success. Oxygen and hydrogen isotopic studies have eliminated seawater as a probable ore-forming fluid, but do not seem to yield a unique solution as to the choice between magmatically or metamorphically generated fluids. Lead isotope data seem to indicate a local host-rock signature, but may not be indicative of fluid source composition. Sulphur isotope data generally indicate local camp-scale homogeneity, and are typically (with notable exceptions such as Hemlo) slightly heavier than the sulphur in massive sulphide deposits. Thus congruent dissolution of primary (mantle-derived) sulphur seems an unlikely mechanism for generation of the heavy sulphur. Perhaps partial decomposition of pyrite through metamorphism to pyrrhotite plus sulphur might yield the appropriate compositions, but considerable evaluation of this and other hypotheses is necessary before a workable genetic model can be accepted.

In addition to some of the problems mentioned above, no one has addressed the problem of the great disparity in abundance of gold deposits between the Archean greenstone belts of Superior Province and the Proterozoic greenstone belts of Churchill Province. In spite of recent significant discoveries at Star Lake, Saskatchewan and Tartan Lake, Manitoba, the amount of gold per unit area of the Flin Flon-Snow Lake greenstone belt is only a tenth of that in an equivalent area of Superior Province. Although simplistic answers to this dichotomy might be proposed (difference in geothermal gradient, different structural/metamorphic history) no systematic comparison of the deposits in these two areas has been made.

Hemlo (J.M. Franklin)

An afternoon session on the geology of the Hemlo deposits provided an abundance of descriptive information that will be of lasting value as carefully documented data on which to build a factually based genetic model. Clearly, access to underground exposures,

as well as careful examination of outcrops and drill core, have provided a new picture of the Hemlo geology. Some of the pertinent points are:

(1) The immediate host rocks are, for the most part, accurately described in non-genetic terms as schists ... highly tectonized rocks, of uncertain origin. The panels of less tectonized volcanic and sedimentary rocks that are adjacent to the ore zones are not so easily identified within the ore zones themselves. The audience is given a picture of the rocks as they are, not as they might have been.

(2) The ore zones are virtually unanimously described as occurring in major zones of microcline alteration; the latter zones are surrounded by sericite schist. There is disagreement on the timing of alteration; Walford and Hugon both documented a post-tectonic emplacement of microcline, with retrograde recrystallization of garnet and amphibole. Burk and others, however, described alteration that has undergone subsequent deformation.

(3) Hugon demonstrated that the deposit lies in the centre of a major ductile deformation zone, probably an oblique thrust fault. In this zone, the Lake Superior Shear Zone, earlier folds are deformed. Burk indicated that at least some of the contacts between lithological units are tectonic juxtapositions; this aspect closely parallels the observations made in many other gold camps as discussed above. He also noted the cross-cutting nature of some of the ore lenses. Hugon's petrofabric analysis indicated that gold was emplaced later than the peak of metamorphism, and using U/Pb age determinations, he suggested that mineralization occurred synchronously with the emplacement of the Cedar Lake Pluton. Kuhns noted that the mineralization is locally in discontinuous and cross-cutting lenses, and also suggested that its emplacement was related to an intrusive event, but discounted the Cedar Lake Pluton as a likely source.

(4) Harris noted that the low-temperature assemblage of antimony and mercury minerals (realgar, stibnite, cinnabar) must have been emplaced after the peak of metamorphism, and that either their constituents were remobilized from earlier-formed, higher-temperature minerals, or that the mineralization system was zoned with respect to temperature, and post-metamorphic.

From the papers just discussed, a set of characteristics of the Hemlo "deposits" emerges that possibly provides a unified "core" description, admittedly with a few ragged edges. The "deposit" formed at an intermediate to late stage in the deformation history of the area. The mineralization is structurally controlled, and both the alteration and ore-mineral assemblages locally cross-cut stratigraphy. The mineral assemblages are typical of those associated with magmatic processes.

Valliant provided an alternative hypothesis,

arguing for stratigraphic control and a partially syngenetic origin. He ascribed the "schists" to a volcanic origin, based on their porphyritic nature (quartz eyes). Use of this textural attribute to determine an origin for such highly tectonized rocks must be done with great caution; other geochemical or petrographic data are required to substantiate a volcanic origin, given the well-documented pervasive tectonic fabric of the ore zone.

One problem not considered fully in this session is the origin of the barite zone that is close to the ore, yet as Burk *et al.* pointed out, is prominent along strike from the deposits for several kilometres. Walford, Kuhns and Burk all noted that the ore, and also the microcline alteration, are locally veined or intimately intermixed with barite; some redistribution or late introduction of barite must have occurred.

Barite zones of the dimensions described for the Hemlo occurrence are present in modern seafloor hydrothermal areas, as well as in the ancient record. Alternatively, elongate barite zones of nearly this length occur in low-temperature veins (~ 100°C) associated with the Sibley Group, a Middle Proterozoic redbed sequence about 180 km west of Hemlo. Primary (syngenetic) barite commonly is forming in modern seafloor hydrothermal systems where barium is an essential component of the hydrothermal fluid, and sulphate is obtained by rapidly heating seawater in contact with the hydrothermal plume. Although in the modern systems barite is always spatially associated with massive sulphide deposits, in the ancient deposits of the sedimentary-associated massive sulphide type, the baritic horizons extend for tens of kilometres away from the base metal areas. Vein barite deposits probably formed in near-surface, highly oxidized hydrothermal systems. In all cases, either oxygen-rich ambient seawater or an oxidative precipitation environment are required to precipitate barite.

The total absence of barite (or any sulphate mineral) in Archean massive sulphide deposits attests to the paucity of available sulphate in the ocean waters of that time. Although sulphate contents of local basins may have been high and thus conducive to local precipitation of sulphate minerals, it seems unlikely that as a general case, barite was commonly precipitated on the seafloor. The amount of deformation that has affected the Hemlo rocks virtually precludes reconstruction of the basin geometry, and thus we must look to other types of evidence to find an answer to the barite problem. The geochemical data presented either in these talks or in other studies are not conclusive; perhaps comparison of the trace element and isotopic characteristics of the Hemlo barite with those of barite samples from deposits that are genetically well understood might prove useful.

I wish to end this discussion with a plea to the geologists that are working at Hemlo to establish a lithological (or litho-stratigraphic)

nomenclature system that is uniformly acceptable to all, and consistent between deposits. Presently, for example, the hornblende schist of Burk *et al.* is the same unit as Walford's and co-workers' metamafic rock and Kuhns' and co-workers' hornblende-plagioclase-biotite schist/amphibolite. I find that correlation of the other units shown in their maps and cross-sections to be very ambiguous. As the three mines are all sharing a common lithologic assemblage, and are really a single orebody, surely a single map legend can be generated for the area. We should encourage the mine geologists to take their crosssections and attempt to reformulate a common legend as a starting point.

In summary, substantial new descriptive data on Precambrian gold deposits were presented at these sessions. Important among these is the variety of alteration minerals which could be useful guides to ore. At Hemlo, we now have a base on which to build genetic models; much further investigation of the alteration minerals, including isotopic and trace element determinations, will probably yield more insight into the mineralization processes.

Epithermal Deposits (J.P.N. Badham)

Considering first features common to the eleven mines described, all were old workings, albeit not necessarily for gold. At Porgera, only alluvial and eluvial materials had been worked, but at all the other localities there had been some rock mining. All of the mines are in or close to major faults. In addition to gold, each deposit contains Ag, Sb, As and often Hg, as well as low quantities of Cu, Pb and Zn. Each is associated with silica alteration and veining, and sericite alteration. All have a spatial and temporal association with felsic magmatism.

Identical features are shown by Archean shear-zone gold deposits — surely a good reason to propose a common model? These features suffice to guide prospectors to either type of mineralization and one might reasonably argue that no more empirical features are needed to find new mineralization — as long as it crops out.

Despite these similarities, four of the mines seem to stand apart geochemically — Porgera, Bessie G, Pueblo Viejo and Red Dome. Each contains significant Te. The only other common feature is that in each instance the associated felsic magma has alkaline affinities. I must conclude that there is a relationship between magma type and mineralization. Such a relationship is empirically prospective. Using Occam's razor I conclude that the relationship is genetic — thus fertile magmas parental to epithermal gold deposits should be distinguishable geochemically. This is a simple conclusion and one that needs testing; how alarming therefore that so few of the papers under discussion present the petrochemistry of their associated magmatic rocks.

The eleven mines under discussion are constrained by the editors to be "epithermal" or "epithermal and other". The definition of "epithermal" is strict, yet few of the authors bother to justify all the requirements of the definition. Ten of the eleven are high level hydrothermal; of these, Salsigne is the only one that seems to fit the "other" category (Carlin is manifestly mesothermal). Of the ten, each resulted from the transport of auriferous fluid through rock to a repository. In some cases the transport distance was minimal (Red Dome, Porgera); in some it was part of a violent blow-out (Kidston); in others the fluid escaped up faults (Bessie G); and in still others the fluid seems to have been somewhat lacking in physical energy but used its chemical potential to eat its way through rocks which thus had to be reactive (Carlin). Because of these differences in transport route and mechanism, deposits which may be genetically similar can be very different in appearance.

Differences can also arise in the depositary. Sometimes gold deposition is attributed to flushing and cooling, sometimes to boiling, or host rock reaction. Again, these differences are superficial. It may be important to appreciate them at the prospect scale but they have little relevance for broader area selection.

The mines under review are large, although surprisingly the papers do not contain tonnage and grade data for Bessie G or Salsigne.

Contained grams Au produced or in proven reserves.	
Carlin*	175.0 x 10 ⁶
El Indio-Tambo	107.8 x 10 ⁶
Kidston	70.3 x 10 ⁶
Salsigne	?
Porgera	375.5 x 10 ⁶
Carolin	6.6 x 10 ⁶
Cannon	34.6 x 10 ⁶
Pueblo Viejo area	600.0 x 10 ⁶
Bessie G	?
Red Dome	27.6 x 10 ⁶
Jerritt Canyon	101.2 x 10 ⁶
* my guess!	

A common feature in the descriptions of these large mines is that at each the mineralizing event was polyphase. Different pulses of mineralization are superimposed. This complexity is responsible for the size of the system and is indeed a characteristic of big *versus* small ones. However, it plays havoc with classification schemes which are based on geochemistry, alteration assemblage or depositional temperature.

If we are required to classify these deposits beyond the term epithermal, I think the best classification is one which takes into account their observational differences and the

causes of these. Having stated that it is transport route, depositional setting and mechanism that determine the differences, the key feature of transport is porosity — whether it is primary, secondary by solution, or secondary by tectonism and fracturing.

A key feature of the depositional site is whether it was merely open space or was reactive. Thus, two deposits which are probably genetically very similar — Carlin and Kidston — are quite separate in present sub-classification. Carlin is an "eat-out reaction dumping" deposit; Kidston is a "blow-out boiling dumping" one. This kind of thinking can guide the prospector as to what to expect in target areas characterized by different host rocks.

An interesting aspect of the deposits under review is that most are Tertiary. Kidston and Red Dome are late Paleozoic, from that well preserved fossil basin and range terrain of NE Australia. The youth of the others might lead one to suppose that gold, like oil, is not a great survivor. Have we really looked for the ancient analogues of these giant epithermal deposits? Veins, porphyries and breccias of all ages are known, but where are the ancient Carlins? Can we extract any empirical and/or genetic data from these descriptions to guide our search for an ancient analogue?

Carlin and Jerritt Canyon are described by the authors as being of the same type. Reading the papers, the common ground appears to consist of structural control in calcareous organic-rich host rocks. The Cannon vein systems traversed similar rocks but ignored them — why? Lack of fluid, temperature, pH, or perhaps just geofickleness. The Porgera system is contained within similar host rocks, but the mineralization remained largely within its parent intrusion. Is Carlin a fugitive Porgera and is there a Porgera underneath Carlin? Red Dome is in calcareous but non-carbonaceous host-rocks — perhaps dissolution porosity was greater and the deposit consequently closer to its source than at Carlin.

I have outlined features which the deposits have in common and which may be used empirically in prospecting. Each paper goes some way toward creating a genetic model for the deposit described, although some seem to assume a consensual model. I tend to believe that formulation of models and understanding the genesis of epithermal deposits are of little use in selecting broad target areas or actually finding deposits. An understanding of the possible nature of mineralization may become very important during drilling — as ably documented by Birak on the discovery of ore hosted by the Hanson Creek Formation at Jerritt Canyon.

In this polemic review, I have not considered what aspect of epithermal deposits is missing from these sessions. I think the most important aspect is comparison and contrasts between the high and low sulphidation epithermal systems — only El Indio is

offered as an example of the former highly valuable type. Geographically, the western North American Cordillera and its Paleozoic Australian analogue are well covered. More papers from the Andean, Central American and SW Pacific regions would have been welcome; the SW Pacific region in particular is becoming a fabulous gold province. Let us hope that the organizers of GOLD'88 can fill in this gap.

I have also commented little on Salsigne. Let us reflect on its setting on a "growth fault", at a facies change between volcanic platform and clastic basin, and its Ba-As-Bi associated geochemistry; at one time certain major Archean gold deposits were being described in just such terms. More recently, they are being properly recognized as epigenetic, with strong structural control.

Accepted 20 December 1986.

For further details about the papers discussed in this report, consult *Proceedings of GOLD'86: an International Symposium on the Geology of Gold*. If your library does not have a copy, it can be ordered from:

Konsult International Inc.
44 Gemini Road
Willowdale, Ontario M2K 2G6

Price: \$50.00 prepaid (includes shipping costs).

Cheque made payable to Patricia Sheahan.