ARCHAEAN GREENSTONE TERRANES: GEOLOGIC EVOLUTION AND METALLOGENESIS

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ABSTRACT The principal components of Archaean granite-greenstone terranes worldwide are briefly outlined. Despite a wealth of local detail that has emerged from these regions over the past two decades there remain to be resolved many fundamental issues.

This paper attempts to highlight Archaean complexity and stresses the intimate interrelationships of processes and responses in the geochemical, lithological, structural and metallogenetic history of granite-greenstone evolution. Although many instances exist where sequential development of greenstone belts can be observed it nevertheless appears that, in terms of geologic and geotectonic evolution, inadequate constraints still provide wide scope for conjecture and speculation as to the events that led up to the final construction of the Archaean shield areas.

INTRODUCTION Any attempt today to provide a universally acceptable synthesis of the geological and geotectonic evolution of Archaean greenstone terranes appears fraught with difficulty. The wealth of new information that has emerged over the past decade and the varied interpretations that have been placed on this data seems to testify to the fact that these ancient terranes were developed in widely contrasting environments and hence, it would be unrealistic to expect a unique solution to be found for their creation.

Archaean terranes worldwide are unquestionably complex regions and are not always adequately exposed or preserved to allow through assessment to be made of all the lithologic, stratigraphic, structural, and igneous interrelationship that exist in these environments. This has resulted, in some cases, in a wide variety of imaginative reconstructions being offered, the latter based upon tenuous supportive evidence and often reflecting more the investigator preferences or prejudices and past geological experiences rather than any degree of originality or mindfulness of the many and varied facets making up any particular Archaean granite-greenstone tract.

Some of the tectonic models that have been proposed to explain the formation of greenstone belts include: (1) comparisons of the early greenstone belt volcanics with modern ophiolites and the late sediments with the flysch and molasse of geosynclines; (2) considerations implying that greenstone belts developed on continental (ensialic) crust occurring in fault-bounded troughs or in rifted areas; (3) counter proposals suggesting that greenstone belts were developed in primitive oceanic (ensimatic) environments, the remnants of which are to be found at the base of the ancient volcano-sedimentary sequences; (4) speculations that catastrophic events such as the surface impacting of extra-terrestrial matter and lunar capture may have been responsible for the production of mafic and ultramafic magmas which require steep geothermal gradients; (5) speculation that mantle plumes and hot spots were accountable for the generation of granitic magmas requiring more moderate geothermal gradients; (6) models visualizing vertically subsiding basins that call on gravitative foundering of the high density volcanic components and the concomitant upward movement of less dense granitic components; and (7) recent attempts applying modern plate tectonic theory, or a modified form of the concept, to the Archaean. Within this framework calc-alkaline volcanic sequences of greenstone belts have been equated with modern island arc assemblages and similarities have also been drawn between greenstone belts and trench-back arc-marginal basin analogues.

Advancement of such widely divergent hypotheses of Archaean crustal evolution may be interpreted to mean that either granite-greenstone terranes formed in a variety of geotectonic settings or, that our understanding of these areas is still far from adequate and that there are insufficient constraints to limit speculation.

It has been suggested, furthermore, that greenstone belts of differing antiquity exist and, in some cases, three ages of greenstone belts have been described from the same geographic region. Wilson (1979, 1981) reported that on the Rhodesian craton of Zimbabwe the main greenstone belts can be divided into Upper Greenstones (2,700 Ma) and Lower Greenstones (age uncertain but possibly 3,000 Ma). These successions, in turn, were developed on a granite-greenstone basement about 3,500 Ma old (Sebakwian Group). Similarly, several ages of greenstone have been suggested by Glikson (1976) for what he termed primary and secondary greenstones that are developed in many parts of the world, including India and Western Australia. The primary greenstones were defined as consisting dominantly of mafic-ultramafic volcanic sequences of once widespread occurrence (primitive oceanic crust), whereas the secondary greenstones, which consist of bimodal mafic-felsic volcanic cycles or of basalt-andesite-rhyolite cycles, are thought to have evolved within linear troughs developed in partly cratonized regions.

If it can be verified that greenstone belts are of widely differing ages then the range of geotectonic settings proposed for these Archaean sequences takes on a new significance. It also becomes apparent that any model suggested for greenstone belt evolution will have to distinguish between the ages of the various components of the greenstone terranes. Failure to achieve this will foster continued speculation and will render suspect any environmental interpretations that may be proposed.

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ARCHAEAN GRANITE-GREENSTONE EVOLUTION

Greenstone Belt volcanism and plutonism

No two greenstone occurrences are identical, reflecting the fact that each developed as a response to a wide range of mutually independent, yet genetically related processes. Despite their individuality a pattern of sequential development can be discerned that is common to many greenstone belts (Anhaeusser, 1981); Anhaeusser *et al.*, 1969; Condie, 1981; Goodwin, 1968; Goodwin and Ridler, 1970; Windley, 1977).

The oldest greenstone sequences generally have anomalous developments of ultramafic-mafic rocks, the latter comprising mainly high-magnesia basalts and peridotites (predominantly komatiites but also including tholeiitic basalts). These subaqueously extruded lava sequences (Viljoen and Viljoen, 1969*a*; Pyke *et al.*, 1973; Glikson and Hickman, 1981), may be accompanied by layered sill-like intrusions differentiated from either ultramafic or mafic magma by gravity-controlled fractional crystallization (Anhaeusser, 1976*a*; MacRae, 1969). The cyclically repetitive layering, which gives rise to dunites, peridotites, harzburgites, ortho- and clino-pyroxenites, norites, gabbros and gabbroic anorthosites, may also partly result from the effects of changes in total pressure causing shifts in phase boundaries on the liquidus relative to the composition of the liquid phase in any given magma chamber (in a manner similar to that outlined for the Bushveld Complex by Cameron, 1980). In addition to the layered complexes, there are also descriptions of intrusive dunite deposits that occur in semiconcordant lenses of peridotite to olivinite composition and which contain numerous nickel sulphide deposits (as for example in Western Australia – Marston *et al.*, 1981). These lenses were emplaced either as subvolcanic sills or as steeply dipping, subconcordant, dyke-like bodies injected along major fracture zones.

In this dominantly volcanogenic environment conditions were at times favourable for the development of subordinate quantities of felsic volcanic and pyroclastic material as well as for the deposition of chemical and volcanogenic sediments (banded iron-formations, calc-silicate rocks, banded cherts, greywackes). Minor bodies of quartz-feldspar porphyry (tonalitic or trondhjemitic in composition and possibly analogous to modern plagiogranites found in oceanic domains) represent subvolcanic intrusions and constitute incipient-or proto-granite development.

Following this primitive, komatiite-dominated, stage of volcanism and plutonism greenstone belt evolution appears to have undergone fundamental chemical changes, the latter brought about largely by the generation of increasingly larger quantities of trondhjemitic or tonalitic magma, the latter derived from the partial melting of primitive ensimatic lithosphere. Low initial isotopic ratios, and ages broadly coincident with the ultramafic-mafic sequences, attest to the close genetic link between trondhjemite and sima during this stage of crustal evolution (the so-called "permobile phase" of Burke and Dewey, 1973). The introduction of the sialic component caused widespread fragmentation of the pre-existing ensimatic domain and led to the development of sodic granite nuclei and the beginnings of cratonization (Anhaeusser, 1973; Glikson, 1979). This episode is recognized, for example, in the Rhodesian craton of Zimbabwe, and in the Barberton region of South Africa and corresponds to the oldest stage of granite-greenstone development.

Subsequent events could now follow widely divergent paths, any of which might be accommodated in one or other of the geotectonic models previously outlined. In some cases the evolving greenstone sequences may have remained in an essentially oceanic domain. Influenced, however, by the presence of a notable sialic component (primitive continental crust) the ensuing volcanism generally resulted in the development of essentially bimodal mafic-to-felsic suites and or of basalt-andesite-dacite-rhyodacite-rhyolite cycles (Baragar and Goodwin, 1969; Glikson, 1976; Viljoen and Viljoen, 1969*b*). The nature of the volcanism and the abundance of associated pyroclastic rocks has led to the view that the calc-alkaline suite evolved in primitive types of island arc systems. Detailed comparisons show, however, that some differences do occur. These include, for example, the presence of some ultramafic extrusives and sill-like bodies that are absent or rare in island arcs and the observation that andesites are uncommon in some greenstone belts. In addition, there are indications that calc-alkaline volcanic complexes in some regions are localized in discrete centres, with intermediate and basic rocks apparently having built large stratovolcanoes. Evidence for this is seen in the Eastern Goldfields Province of Western Australia where Giles (1980) described laharic deposits as well as variety of lithic-, crystal- and vitric-tuffs showing marked lateral facies changes on the scale of many kilometres.

Most of the volcanic rocks show a common development of pillows and crystalline quench textures suggesting rapid subaqueous extrusion and crystallization. Volcano-sedimentary cycles appear to be present in most greenstone belts and are usually terminated by felsic fragmental rocks (coarse breccia, laharic flows, tuff breccia, tuffs, and coarse-grained volcaniclastic sedimentary units) which collectively formed autoclastic, pyroclastic and epiclastic debris in the vicinity of active vents (Lowe, 1980).

Away from vent complexes, thin felsic tuff units are frequently capped by chert layers. These, as well as thin carbonate layers and terrigenous clastic rocks, occur as the most common interflow units. The cherts mostly include banded black, grey and white chert, banded ferruginous chert, carbonaceous chert and a variety of iron-rich cherty rocks loosely referred to as banded iron-formation or jaspilite. The banded iron-formations are of various types and may include oxide, carbonate, sulphide and silicate facies varieties. These essentially chemical sediments generally have wide lateral extent and represent major breaks in the depositional evolution of greenstone belts. The facies variations encountered provide some indications as to the original depositional environment of the sediments. The terrigeneous clastic rocks show an irregular distribution. In many of the oldest preserved volcanic sequences, including the Onverwacht and Warrawoona groups and greenstone belts of the Indian Shield, this material consists solely of volcanogenic epiclastic debris – there being no evidence to indicate a continental, plutonic, metamorphic or older sedimentary provenance. Younger, post 3,000 Ma old, greenstone belts on the other hand commonly include a small but important component of non-volcanogenic clastic detritus within the volcanic suite. Shale, argillite, mudstone, and quartzose sandstone, and conglomerate containing clasts of older plutonic or metamorphic rocks, have been described as interflow sediments from areas such as the Yilgarn Block, the Bulawayan Group on the Rhodesian craton, and from many formations in the Canadian Shield (Lowe, 1980).

In some regions subvolcanic porphyry bodies, genetically linked with the developing volcanic sequences, were emplaced into the greenstone belts. These bodies are similar to the quartz-feldspar porphyry intrusions associated with the ultramafic-mafic assemblages but tend to be granodioritic rather than trondhjemitic – again reflecting progressive chemical evolutionary changes in the developing greenstone belt systems.

Granite evolution In the older environments the events within the developing greenstone piles were accompanied by contemporaneous magmatic activity including the generation and emplacement of granitic igneous bodies. These were almost invariably soda-rich to start with but their compositional characteristics were no doubt determined by the nature of the parental material, as well as the degree of partial melting, involved in their genesis. In the younger greenstone environments, where a pre-existing sialic crust is indicated, the granitic history may be less certain as a consequence of superimposition of events, coupled with the mixing of newly formed magma with earlier-formed sial. Variations in the initial $^{87}Sr/^{86}Sr$ ratios and age determinations help to fingerprint these events and provide petrogenetic guidelines.

Where no older sialic basement can be detected (as is believed to be the case in the Barberton region – Anhaeusser and Robb, 1981) the sequence of granitic events reflects a progressive change from soda-rich tonalite and trondhjemite gneisses and associated migmatites (3,200-3,500 Ma with very low initial $^{87}Sr/^{86}Sr$ ratios of approximately 0.7000 – Barton, 1981) to multicomponent, potasn-rich batholiths comprised dominantly of granodiorite, adamellite, and granite (*sensu stricto*). These batholiths and their associated marginal migmatite terranes are approximately 3,000-3,200 Ma old (with higher initial $^{87}Sr/^{86}Sr$ ratios of approximately 0.7013 – Barton, 1981) and are considered to have formed from the partial melting of the preexisting tonalitic/trondhjemitic terrane following a widespread de-gassing of volatiles derived from a deep-seated origin beneath the crust of the Kaapvaal craton. The upward migration of these volatiles reduced the solidus temperature of the tonalite/trondhjemite gneisses and resulted in extensive partial melting of these earlier formed rocks. The magma thus generated began to progressively coalesce upwards forming the high-level batholiths. Together with their parental gneisses and associated migmatites, the development of the batholiths constituted one of the main events contributing to cratonization and subsequent tectonic stability of the Kaapvaal and Rhodesian cratonic blocks (Anhaeusser and Robb, 1981, 1982; Robb *et al.*, 1982).

In some regions small, discrete, post-tectonic plutons were emplaced late in the evolution of granite-greenstone terranes. These bodies did not contribute significantly either to the construction or stablization of the early continental crust but are characterized by diverse ages, origins, and compositions and, collectively, represent the final magmatic event in the development of the Archaean granitic crust (Anhaeusser and Robb, 1981; Robb, 1981*b*).

Sedimentation While the granitic rocks were evolving, and at the same time being emplaced (often diapirically) into the greenstone environment, they caused progressive elevation of the subjacent volcanic sequences and ultimately began to act as provenance regions from which was shed increasing quantities of clastic detritus. Initially, much of the material eroded was derived from the weathering of uplifted greenstone components and this contributed to the frequently encountered turbidite sequences made up of vast accumulations of greywackes and shales. Progressive unroofing of rising granitoid masses is reflected in the changing nature of the sediments commonly encountered in the upper formations of most greenstone belts. Greywackes and shales give way to siltstone, sandstones, quartzites and conglomerates and studies have demonstrated the existence of a deep--to shallow-water clastic association dominated by thick turbiditic submarine fan or flysch sequences juxtaposed with subaerial alluvial fan facies. Generally absent, or scarsely represented, are shallow-water clastic shelf and shoreline sequences (Lowe, 1980).

The turbidite sequences are indicative of deep water sedimentation whereas the evidence for shallow water conditions include, locally, the presence of stromatolitic limestones, stratiform barite (some of which may be diagenetically replacing evaporitic deposits of gypsum), and a host of sedimentary textures and structures that include cross-bedding, ripple marks and mud-cracks – all features that have been variously interpreted as indicative of deltaic plain, tidal flat, channel, shoal, barrier island or shallow-marine shelf environments (Eriksson, 1977, 1978; Lowe, 1980).

Accompanying the clastic sedimentation were isolated and generally minor outpourings of lavas and pyroclastic rocks together with the development of jaspilites and banded iron--formations. The volcanic rocks again reflect the changing conditions of the crust as the greenstone belt evolved. Flows of alkali mafic trachytes and leucitic lavas and pyroclasts have, for example, been identified in the Fig Tree sediments in the Barberton area and in the Timiskaming sediments near Kirkland Lake, Ontario (Cooke and Moorhouse, 1969; Visser *et al.*, 1956). Although such occurrences appear to be rare, their position toward the top of greenstone-belt piles suggests that they may be the result of contamination of magma during its ascent through a progressively thickening protocontinental crust.

Structure and Metamorphism Throughout the development of the granite-greenstone terranes there is abundant evidence to demonstrate the secular variation in the nature and style of the volcanism, plutonism and sedimention manifest in these regions. In addition, there are sequential structural and metamorphic features that may be identified. The distinctive deformational styles of Archaean complexes are unique. Anhaeusser (1975) visualized essentially two main stages in their tectonic history. The first of these relates to the primary geotectonic setting and remains enigmatic. All that can be demonstrated with certainty is the fact that the earliest volcanism and sedimentation commenced in progressively subsiding depositories located on unstable primitive lithosphere. Later, and following incipient cratonization, younger greenstone depositories were probably initiated as a result of crustal fracturing and the development of intracratonic rifting. Large, fault-bounded troughs would then be filled by deep-seated magmas making their way to surface along mantle-tapping fractures as well as by terrigenous detritus emanating from the protocontinental masses.

The first stage in the tectonic evolution of Archaean complexes was probably dominated largely by gravitational influences coupled with high heat flow and a rapidly convecting system involving closely spaced cells. Foundering lithospheric slabs caught up in this highly mobile environment could have undergone phase changes from amphibolites to basic granulite or eclogite that subsequently generated the first tonalitic liquids by partial fusion (Green and Rigwood, 1968; Lambert and Wyllie, 1972).

Such melts may have coalesced to form a tonalitic/trondhjemitic substratum that, because of density and ductility contrasts with the overlying supracrustal components, began to react diapirically and eventually gave rise to the typical Archaean "granite-greenstone pattern" described by Anhaeusser *et al.* (1969). This pattern is exemplified by Macgregor's (1951) portrayal of the "gregarious batholith" map of the Rhodesian craton, as well as by the diapirism demonstrated by Schwerdtner and Lumbers (1980) in the Superior Province of Ontario.

Many of the diapiric bodies crystallized at depth and only made their final ascent in stages as semi-consolidated gneissic plutons. In the Barberton Mountain Land this view is supported by geochronological as well as Sr-isotopic data which suggests an episodic introduction of the trondhjemitic plutons and indicates, furthermore, that diapiric emplacement may or may not have closely accompanied original crystallization of these rock units (Barton, 1982). Although a semi-solid state of intrusion of the diapiric gneiss plutons is frequently indicated, there is ample evidence to demonstrate that unequivocal magmatic relationships also exist between some of the tonalite/trondhjemite plutons and the supracrustal greenstone successions (cross-cutting or truncated contacts, lit-par-lit magma injection, agmatite development, contact metamorphic features).

In some of the older shield areas this initial granitic episode may have been so extensive as to all but destroy entirely the early greenstone succession. All that may be preserved are variably sized greenstone enclaves or xenoliths and a wide variety of migmatites derived essentially from granite-greenstone interaction (Anhaeusser and Robb, 1980; Robb, 1981*a*). In this setting even some of the larger greenstone sequences, such as the Barberton greenstone belt (100 km long by 30 km wide), can be viewed as xenoliths enveloped by vast granitic tracts.

Structures produced during Stage 1 in greenstone belt tectonic evolution were predominantly linear features promoted by gravity slumping of the troughs of lavas and sediments (Anhaeusser, 1975). These are manifest as variably plunging isoclinal or recumbent folds formed in preferentially developing synclinoria as well as steeply inclined faults or slides (and, less commonly, anticlines and nappe-structures). Deeply infolded sequences experimented variable degrees of anatexis and, together with the widespread regional development of granitic rocks, contributed to the diapiric invasion of the greenstone belt sequences. Stage 2 in the tectonic history identifies the added structural complexity imposed by the interaction of diapiric gneiss plutons both on themselves and on the remnant greenstone sequences. Evidence exists of diapirs within diapirs and, within the greenstone belts and in the narrow septa separating invading plutons, differential compression commonly resulted in isolinal folding accompanied by the development of a strong cleavage or schistosity that invariably parallels greenstone contacts and foliation directions in adjacent gneisses. Deformation features, include flattened pebbles and pillow structures, mineral reorientation, transcurrent faulting, drag and disharmonic folds, fractures and joints and a host of superimposed small- and large-scale folds (conjugate, chevron and kink-band folds).

The plutonism and diapirism produced, in addition, a distinctive low-pressure/high-temperature variety of metamorphism (Abukuma-type) in most greenstone terranes. Significant features of Archaean metamorphism include the telescoped nature of the metamorphic aureoles at granite-greenstone contacts and the bimodal nature of the mineral facies (amphibolite-greenschist). Notably absent is the "paired metamorphism" so characteristic of the circum-Pacific island areas and the blueschist metamorphic assemblages like those found in Phanerozoic orogenic belts (Engel, 1968). Successive stages of granite and pegmatite emplacement influenced the nature and style of metamorphism locally, and some regions well-removed from granite contacts show virtually no metamorphism at all.

Although the tectono-thermal history of granite-greenstone terranes is outlined above as occurring essentially in two stages this has been done merely to facilitate description. In reality, the features and events observed in these belts result from a continuum of processes, each eliciting responses that are either unique or that interact with each other sequentially or in a random manner.

ARCHAEAN METALLOGENESIS A greater understanding of the geotectonic setting and evolutionary style of granite-greenstone terranes should influence the approach adopted in assessing a region's metallogenetic potential. At present it is recognized that there is a strong genetic link between mineral types and host rock compositions (Anhaeusser, 1976*b*, 1981; Hutchinson, 1980, 1981; Hutchinson *et al.*, 1971). Mineralization in the Archaean is extremely varied but in terms of the evolutionary stratigraphic scheme previously outlined the mineral types can be subdivided into those that favour development or association with ultramafic/mafic rocks (mainly gold, nickel, chrome, chrysotile asbestos, talc and magnesite), those that occur predominantly in mafic-to-felsic successions (mainly massive sulphide deposits containing important copper-zinc-gold-silver mineralization and lesser occurrences of antimony, arsenic, lead, mercury and tungsten, as well as iron-formations), and those that favour development in sedimentary sequences (mainly iron-formations, limestone, barite, and placer deposits of gold and tin, as well as syngenetic stratiform gold occurrences). Lastly, there is mineralization that is initially restricted to the granitic rocks, having generally been concentrated in residual liquids that developed as pegmatites and other late granitic veins and apophyses (tin, tantalum, berylium, lithium, bismuth, mica, molybdenum, corundum and emeralds).

Many factors determine the nature and distribution of mineral deposits and include heterogeneities in the mantle compositions, as appears to be indicated, for example, in southern Africa where anomalous developments of chromite exist. In this relatively small geographic region successive geological complexes have, over a period of 1,800 Ma, tapped chromite from a mantle source, with the result that approximately two-thirds of the Earth's known chrome resources are concentrated in rocks such as the Archaean Sebakwian and Mashaba ultramafic sequences as well as the Great Dyke in the Rhodesian craton, and the Bushveld Igneous Complex in the Kaapvaal craton (Anhaeusser, 1976*b*).

Anhaeusser (1981) also pointed to two other regional anomalies, not necessarily linked with mantle differences. These relate to (1) the prevalence of Cu-Zn-Au-Ag volcanogenic massive sulphide deposits found throughout the Canadian Archaean (Boyle, 1976; Franklin *et al.*, 1981; Sangster, 1972) and their paucity elsewhere, and (2) the greater abundance of Archaean gold in southern Africa relative to Canada and Western Australia (Anhaeusser, 1976*c*). Suitable explanations for these anomalies still have to be provided but may be associated with such factors as relative ages of the greenstone sequences, coupled with attendant evolutionary chemical differences both of magma-types and of the atmosphere and hydrosphere. Changing crustal conditions from early to late Archaean may also have played a significant role, particularly if some form of plate tectonic process was operative. As mentioned previously there appears to be a consensus view that some form of modified plate tectonic processes applied during the Archaean. Opinions vary but Anhaeusser (1981) and Hutchinson (1980, 1981) both visualized that Archaean tectonism involved mainly vertical movement and was dominated by subsidence.

In terms of value the most significant Archaean mineral deposits worldwide include the Cu-Zn-Au-Ag massive base metal sulphide deposits, the nickel (copper) sulphide deposits and the occurrences of gold mineralization. This is followed by locally important deposits of iron ore, chrome, chrysotile asbestos and antimony. The remaining mineral types encountered in Archaean terranes are generally not of major significance.

Although there is the close genetic link between mineral types and host rocks of specific compositions it also remains to be determined why in some regions mineralization is more prevalent than in others. A good example of this nature is the prominence of important nickel sulphide deposits in the ultramafic-mafic (komatiitic to tholeiitic) sequences in the Yilgarn Block of Western Australia (Marston *et al.*, 1981) and their apparent absence in the Barberton greenstone belt where rocks of this association are extensively developed. Here the greater age of the Barberton sequences (and hence the possible significance of this on the nature of the geotectonic setting relative to the formations in the Yilgarn Block) may be significant. The age factor and the attendant subtleties of the geochemistry of the ultramafic-mafic rocks may be important as nickel occurrences are also not all that prevalent in the older Pilbara Block of Western Australia. Nickel sulphide occurrences are also significant in the Canadian and Zimbabwean greenstone belts (Naldrett, 1981) where they also occur in volcanic sequences younger than those in both the Barberton and Pilbara regions. The above argument runs into difficulties in attempting to explain why the Canadian greenstone belts are so well-endowed with massive sulphide Cu-Zn-Au-Ag deposits whereas in both the Yilgarn Block and in Zimbabwe the so-called younger greenstones (± 2,700 Ma old) are virtually devoid of this type of occurrence.

In concluding this review and assessment of Archaean metallogenesis a final consideration adopted by Anhaeusser (1981) was to view many of the ore types from these primitive environments not as primary deposits *sensu stricto* but rather as secondary deposits formed as a result of superimposed processes acting upon the host rocks during or subsequent to their formation and deposition. A good example of this is chrysotile asbestos which more than likely developed not when the host rock dunite first crystallized but later, following (1) serpentinization of the dunites and (2) tectonic disturbance that is pre-requisite for fibre formation (Anhaeusser, 1976*a*).

The same concept can be applied to many other Archaean mineral deposits, including gold. In some cases mineral concentrations are due to primary factors such as magma differentiation, or sulphide-silicate immiscibility. However, Anhaeusser (1981) argued that many ore concentrations are due to secondary influences superimposed upon the volcanogenic greenstone belt environment, thereby resulting in the release of elements or metals often entrapped in crystal lattices of minerals developed in lava piles. Subsequent mobilization resulting from such on-going events as successive stages of granite intrusion, deformation, metamorphism and a range of chemical processes, could result in the solution and reprecipitation of metals into suitable structural or chemically reactive sites as to ensure concentrations that could ultimately be exploited as ore deposits.

Finally, it has been the intention in this paper to demonstrate and emphasize the extreme complexity of Archaean granite-greenstone terranes. The terse remarks made at the outset of the contribution may have more relevance now that it is apparent that there are still a great many imponderables with regard to Archaean evolution, petrogenesis and metallogenesis. The numerous details assembled so far from all corners of the Archaean globe do not yet provide adequate constraints on attempts, like this one, to summarize and synthesize Archaean geologic evolution.

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Recebido em 15 de agosto de 1982