

## THE ASSOCIATION OF SOME NICKEL SULFIDE DEPOSITS WITH KOMATIITIC VOLCANISM IN RHODESIA

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### ABSTRACT

During the past ten years a number of small nickel sulfide deposits have been discovered in the Archean greenstone belts of the Rhodesian Midlands. These include the Damba deposits, described here in some detail, and five other occurrences whose principal features are summarized. A regional investigation and a reannotation of existing maps covering 230,000 km<sup>2</sup> of the Rhodesian basement show that the deposits are clearly associated with komatiitic volcanism and that komatiitic volcanic rocks are more widespread in the Bulawayan Group than the maps suggest. At least four of the komatiite sequences have the same simple and regular stratigraphy of peridotitic komatiite - pyroxenitic komatiite - basaltic komatiite, with the basaltic varieties making up the major part of individual successions. Komatiitic and tholeiitic magmatism was both concomitant and overlapping within the Bulawayan Group. All the nickel deposits are found at, or close to, the contact between the Sebakwian and Bulawayan Groups and are an integral part of the very first volcanic unit in the Bulawayan Group. The Damba deposits are within an extrusive peridotite unit and include one instance of mineralization overlying what may have been a feeder conduit. Several of the other deposits occur in, or are closely associated with, cross-cutting peridotite bodies that are interpreted as volcanic necks or vents; the deposits seem to lie in sites that have acted as volcanic centres both prior to and following peridotite-ore emplacement. Both the detailed setting and configuration of the komatiitic sequence at the Shangani deposit suggest that volcanism was of a fissure type.

### SOMMAIRE

Au cours de la dernière décennie, plusieurs petits gisements nickelifères ont été découverts dans les ceintures de roches vertes archéennes en Rhodésie centrale. Parmi ceux-ci figurent les gisements Dam-

ba, décrits ici en détail; nous présentons aussi les faits saillants concernant cinq autres de ces gisements. Un relevé régional et une ré-annotation des cartes existantes couvrant 230 000 km<sup>2</sup> du socle Rhodésien montrent clairement que la minéralisation est associée au volcanisme komatiitique, plus répandu dans le groupe Bulawayen que ne l'indiquent les cartes. Au moins quatre séquences komatiitiques possèdent la même stratigraphie simple et régulière (komatiite péridotitique-komatiite pyroxénitique-komatiite basaltique), dont les roches basaltiques constituent la majeure partie dans chacune des séquences. Le magmatisme, dans le groupe Bulawayen, a été tholéitique et komatiitique, tantôt simultanément, tantôt alternativement. Tous les gisements se trouvent près du contact des groupes Sebakwien et Bulawayen, et forment partie intégrale de la toute première unité volcanique du groupe Bulawayen. Les gisements Damba sont dans une extrusion péridotitique; dans un cas, la minéralisation semble localisée au-dessus d'un conduit d'alimentation volcanique. Plusieurs des gisements sont intimement recoupés par des intrusions de péridotite qui représenteraient des necks ou venues volcaniques; ces gisements sont situés en des centres d'une activité volcanique antérieure et postérieure à la mise en place du minerai. Tant par son emplacement que par sa forme, la séquence komatiitique du gisement Shangani indique un volcanisme de type fissural.

(Traduit par la Rédaction)

### INTRODUCTION

During the late 1960s and early 1970s a number of nickel sulfide deposits were discovered in the Rhodesian Midlands (Fig. 1). Although by world standards they are small and of low grade, two of the discoveries are currently in production at Shangani (Philpott 1975, Viljoen *et al.* 1976) and Epoch. The others include Damba, Hunters Road (Brand 1976) and Selukwe which are either subeconomic or await a more favorable economic climate for development. Several other minor or untested occurrences have also been located.

As part of a broad-scale evaluation of the

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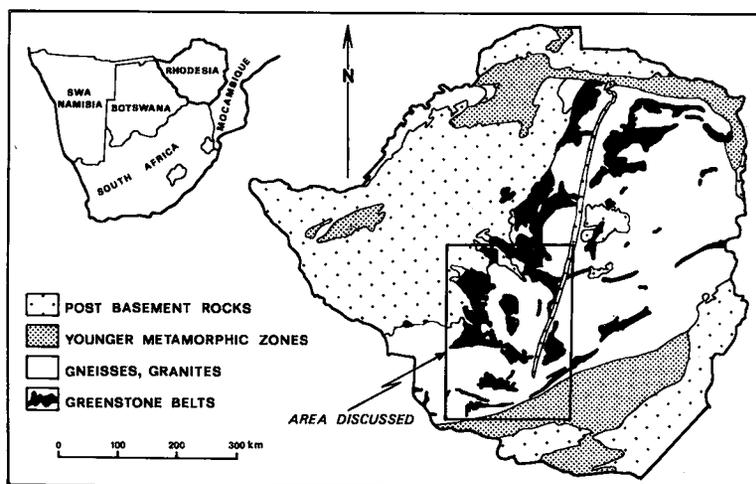


FIG. 1. Locality map, adapted from Bliss & Stidolph (1969).

base-metal potential of the Rhodesian basement complex, a compilation study and reannotation of existing maps was implemented over some 230,000 km<sup>2</sup> of this granite-greenstone terrain. The basic data were derived from published and unpublished maps of the Rhodesia Geological Survey at scales of between 1:50,000 and 1:1,000,000. Along with company information, this was compiled at a scale of 1:250,000 and augmented by four months field work. The Survey maps have a spread of publication dates from 1920 to 1975, resulting in major terminological differences between the sheets. The field work was thus directed at resolving these differences and at examination of lithologies of exploration interest with the aim of producing a unified geological map that reflects current knowledge.

Part of this work, coupled with a detailed examination of the Damba nickel deposits, has shown a rather striking association of the nickel deposits with komatiitic volcanism in the Midlands area. Some of these results are presented here; a more detailed discussion of the geological and geochemical results is to be given elsewhere (Williams *in prep.*). Note that the definitions of peridotitic, pyroxenitic and basaltic komatiite used here are those of Arndt *et al.* (1977); see also discussion of this terminology by Williams & Furnell (1979). Distinction between basaltic komatiite and tholeiite is based largely on texture, MgO content and field association with spinifex-textured ultramafic komatiites.

#### GENERAL GEOLOGY

The Rhodesian Archean granite-greenstone terrain provides some of the best information available anywhere on the relationships between granite and greenstone and between the various volcanic rock types. This is due to comprehensive, good-quality Survey mapping, continuity of exposure and relatively low grades of metamorphism. Bliss & Stidolph (1969) and Wilson (1973) have provided recent summaries of the geology and possible development of the Rhodesian craton which update Macgregor's (1951) classic account. The official Rhodesian geological map (1:1,000,000) has also been recently revised (7th edition, 1977).

Macgregor (1951) divided the greenstone belt succession in Rhodesia into three "systems" (now called Groups): the Sebakwian Group at the base, overlain in turn by the Bulawayan and Shamvaian Groups. This subdivision is still retained though the extent of the Sebakwian and Shamvaian Groups is less than as originally defined:

*Shamvaian Group:* Poorly sorted sediments (grits, greywackes, arkoses and conglomerates with some felsic volcanic rocks. Not discussed further in this paper.

*Bulawayan Group:* Dominantly komatiitic, basaltic and andesitic volcanic rocks with associated sedimentary units (arkose, grit, phyllite, conglomerate and banded iron-formation).

*Sebakwian Group:* Mafic and felsic volcanic

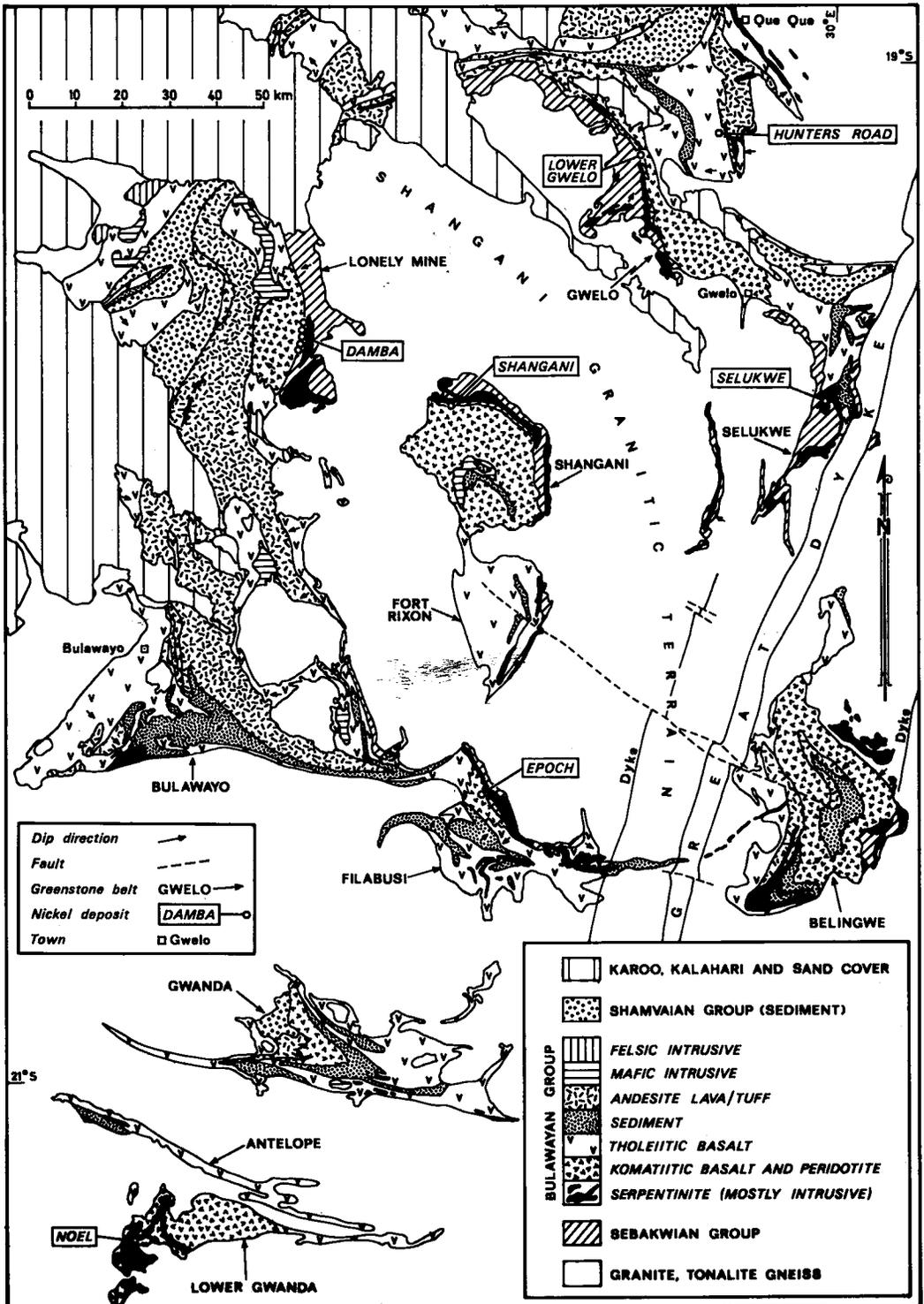


FIG. 2. Simplified geology of part of the compilation area showing nickel deposit localities. Data sources are given in the text.

rocks, quartz-sericite schists, micaceous quartzites, phyllite and banded iron-formation with ultramafic intrusive rocks (of Bulawayan or later age) and some extrusive equivalents.

Bliss & Stidolph (1969, p. 309) noted that the existence of the Sebakwian as a separate group is based on the recognition of an unconformity between it and the overlying Bulawayan Group together with a marked change in structure and metamorphic grade across the contact. The type-area unconformity has been questioned by a number of workers (Harrison 1968, Bliss & Stidolph 1969, Wilson 1973) and, as a result, many of the areas previously shown as being Sebakwian have been included within the Bulawayan Group on the latest Rhodesia geological map. The term Sebakwian will be used here in the sense of Bliss & Stidolph (1969) but without the implication of an unconformity between it and the Bulawayan Group (Williams *in prep.*). This contact marks an important change in volcanism irrespective of whether a major time break is involved; to this author, the placing of Sebakwian-type sequences into the Bulawayan Group seems unfortunate.

The geology of the area of interest is shown in Figure 2. This is only part of the geological compilation and has been greatly simplified for reproduction at this scale. The geology is largely a reinterpretation of the work of Macgregor (1928, 1937), Keep (1929), Phaup (1932, 1933), Ferguson (1934), Macgregor *et al.* (1937), Amm (1940, 1946), Tyndale-Biscoe (1940, 1949), Worst (1956), Stowe (1968) and Harrison (1969, 1970). The Shangani granitic terrain forms the dominant structural feature in the area and the greenstone remnants dip outward from it at 40–80°. As many authors have observed (*e.g.*, Macgregor 1951), the greenstone belts themselves are dominantly synclinal with broadly north-south-trending fold axes in the Lonely Mine, Shangani, Filabusi, Belingwe and Gwelo belts and east-west trends in the Gwanda and Lower Gwanda belts.

#### *Sebakwian Group*

The oldest greenstone belt material in the area belongs to the Sebakwian Group and is best developed in the Shangani, Lonely Mine, Gwelo and Selukwe belts where it rims the northern edge of the Shangani granitic terrain; see Bliss & Stidolph (1969) and Wilson (1973) for discussions of pre-Sebakwian greenstone material. Generally the Sebakwian Group consists of both sedimentary and volcanic rocks,

but it is usually characterized by quartzofeldspathic sedimentary units, quartz-mica schists, phyllites and quartzites, many of which are of volcanoclastic origin, together with banded iron-formation, a wide variety of mafic schists and some ultramafic lavas. The Sebakwian Group is intruded by ubiquitous layered sills consisting dominantly of serpentinite, with minor metapyroxenite and metagabbro (Macgregor 1937, Amm 1946, Tyndale-Biscoe 1949, Harrison 1969, Viljoen *et al.* 1976).

In the western part of the Gwelo belt (35 km northwest of Gwelo: Fig. 2), Macgregor (1937) recognized a NE-SW axis of folding in the Sebakwian Group that is not shown in the overlying Bulawayan Group. However, in the Shangani and Lonely Mine belts there is no evidence of any major time break despite the change from felsic to mafic volcanism.

#### *Bulawayan Group*

The Bulawayan Group is generally regarded as consisting largely of basaltic and andesitic volcanic rocks with locally abundant sedimentary units and banded iron formation and relatively minor acid volcanic rocks (Macgregor 1951, Bliss & Stidolph 1969). A number of authors, including Macgregor (1928), Keep (1929) and Phaup (1933), have described ultramafic rocks with basaltic textures from within the Bulawayan Group, but few attempts were made to distinguish these rocks on their maps. The main change to the existing published maps made in compiling Figure 2 is the inclusion of these rocks as a separate group of komatiitic basalt and peridotite. It is stressed that their distribution, as shown in Figure 2, is largely a result of road traversing reconnaissance and a reassessment of information in the various Survey bulletins. As a result the boundaries shown are approximate and would need much further field work to be defined accurately.

As can be seen in Figure 2, the komatiites are a major constituent of the Bulawayan Group. They also occur in the Sebakwian Group: a good example (shown as serpentinite in Fig. 2) occurs along the eastern edge of the Shangani belt (Viljoen *et al.* 1976). In the Bulawayan Group itself the komatiites occur in remarkably consistent and simple sequences like that described by Viljoen *et al.* (1976). The sequence at Damba seems typical of this volcanic association and will be described in detail later.

The komatiites give way to, and interfinger with, relatively monotonous successions of predominantly pillowed tholeiitic basalts, which in places also rest on the underlying Sebakwian

Group and were apparently extruded concomitantly with the komatiites. Andesite lavas and widespread agglomerates (Macgregor 1937, Macgregor *et al.* 1937, Harrison 1970) commonly overlie either tholeiitic or komatiitic basalt in the western half of the map area, but in the eastern half (Gwelo and Belingwe belts) thinner but otherwise similar andesites underlie the typical basaltic volcanic rocks of the Bulawayan Group. Sedimentary units within the Bulawayan Group are locally abundant (Belingwe, Gwelo, Filabusi and Bulawayo belts) and include banded iron-formations, phyllites, limestones (Bickle *et al.* 1975) as well as greywackes, grits and conglomerates (Macgregor 1937, Amm 1940).

### THE NICKEL DEPOSITS

Although the nickel deposits so far located in the map area (Fig. 2) differ from one another, they have associational characteristics that indicate a genetic link with the evolution of Bulawayan Group volcanic rocks. The most striking feature is the restriction of almost all the deposits to a stratigraphic interval of less than 500 m, straddling the contact between the Sebakwian and Bulawayan Groups. It seems that the mineralization is an intrinsic part of the first volcanic activity that initiated the Bulawayan Group. As will be shown in the following descriptions of some of the deposits, the associated volcanism is komatiitic.

#### Damba

The Damba nickel deposits provide a clear example of the relationship between mineralization and volcanism; they will be described in some detail although this is a preliminary report based entirely on drilling information. Situated 75 km north-northeast of Bulawayo in the Lonely Mine belt (Fig. 2), the deposits are spread over a strike length of 7 km. The first of the deposits was discovered in 1968 below a showing of nickel-rich silicates and gaspeite, and subsequent exploration to 1975 had located five separate deposits.

The regional geology has been outlined by Macgregor (1928) but surface mapping in the area is hampered by poor exposure; the stratigraphy that has been established in areas of mineralization (Fig. 3) is based largely on drilling results. The sequence has a general north-south strike and a regional westerly dip of 45-50°. The Sebakwian Group here consists of various amphibolites, hornblende and quartz-

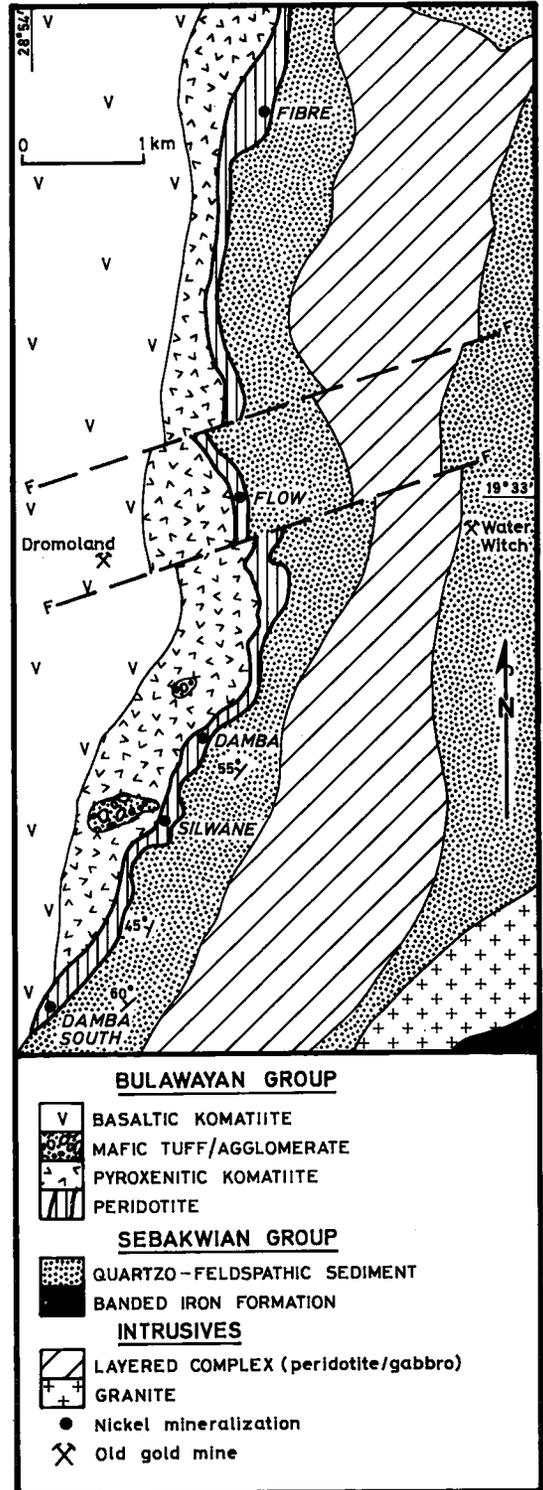


FIG. 3. Damba surface geology. Map, in part, from work by D.M. Anderson, M.J. and R.P. Viljoen.

mica schists, banded iron-formations and nearer the top, well-preserved, apparently volcanogenic, quartzofeldspathic sedimentary rocks and inter-layered pyritic carbonaceous shales. The sequence is intruded by several large peridotite-pyroxenite-gabbro layered complexes and by a number of strike-persistent multiple dolerite sills.

The Bulawayan Group appears to lie conformably on the quartzofeldspathic sedimentary rocks and minor cherts that terminate the Sebakwian Group. In the zone that includes the nickel deposits (Figs. 2, 3), the Bulawayan Group volcanism was komatiitic and the succession can be divided into three units: Unit 1 (at the base): ore-zone peridotite (0–200 m thick); Unit 2: olivine-bearing pyroxenitic komatiite (0–300 m thick); Unit 3: basaltic komatiite (up to 7 km thick).

In most areas, unit 1, the ore-zone peridotite, rests directly on the underlying Sebakwian Group, but in some parts a thin wedge (< 40 m thick) of basaltic komatiite separates peridotite from sedimentary units. Mapping and drilling have shown that although the peridotite thickens and thins irregularly it is continuous over a strike of some 9 km.

The principal rock types that now make up the peridotite are serpentinites, carbonated serpentinites and talc-carbonate rocks. Although their distribution is mostly erratic and unrelated

to original rock type, the serpentinites are generally more common in thicker parts of the peridotite and give way to talc-carbonate rocks in thinner zones. Primary textures are preserved in some of the less intensely altered rocks and show completely serpentinized subhedral to euhedral olivine set in a matrix of subhedral to skeletal uralitized or serpentinized clinopyroxene, minor chromite and a densely opaque-dusted groundmass of chlorite or serpentine. With increased serpentinization the matrix is also completely serpentinized. No systematic variation in olivine grain-size could be detected; the average size is 1.0–1.5 mm with some scattered larger, lath-like crystals ranging from 3–10 mm in length.

Spinifex texture in a number of forms is well developed in specific zones in the peridotite. Its main occurrence is at the top of the peridotite unit and it seems better developed in this position, where the peridotite is thicker (Fig. 4). Internal spinifex units also occur and the maximum number intersected in any drillhole is four. The types represented include typical platy varieties and examples with randomly oriented, long (10 mm) skeletal crystals, with both types showing widely varying grain sizes. Most of the spinifex zones have amygdales ranging in size from 3–10 mm, and filled with chlorite, carbonate or sulfide.

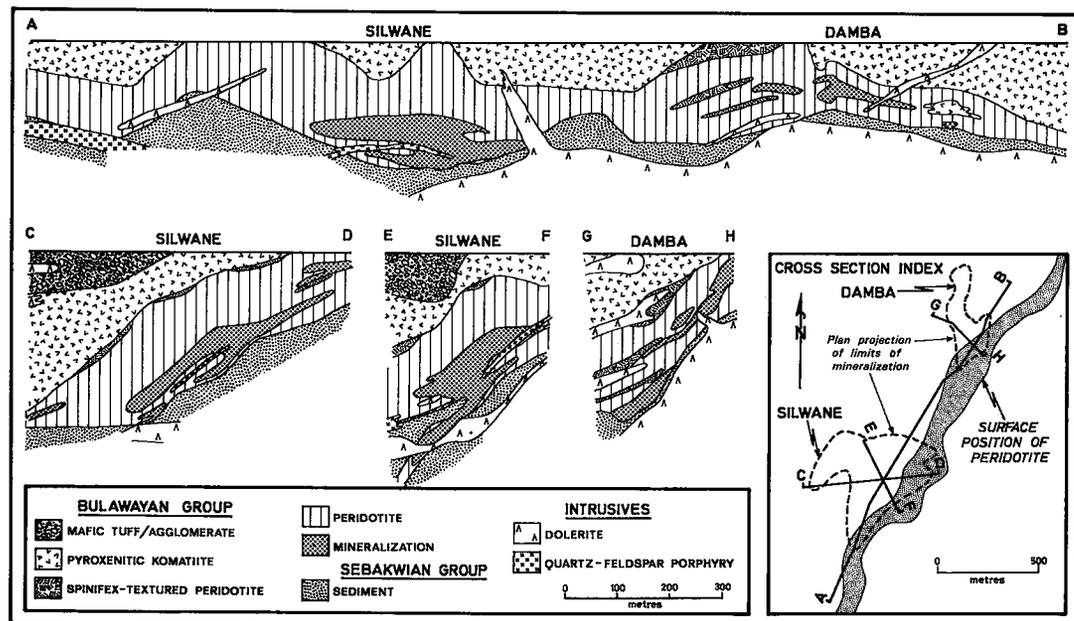


FIG. 4. Damba and Silwane strike and dip sections.

Quite convincing flow-top breccias and possible ultramafic tuffs can be recognized in several drillholes, always associated with spinifex units. The breccias seem to be more common in the flows with strongly amygdaloidal spinifex zones. Flow-top breccias, widespread amygdaloidal structures, repeated spinifex units and the textural and compositional similarity between the olivine-poor zones within the peridotite and olivine-rich basalt flows in the hanging wall seem to indicate that the peridotite is in large part extrusive.

Unit 2 overlies the peridotite and is made up of olivine-bearing pyroxenitic and "glassy" komatiitic lavas. Individual flows, which are not pillowed, are up to 8 m thick; thin tuff units and cracked and broken flow tops can be seen marking the tops of many of the flows. Although now converted to tremolite, talc and chlorite, primary textures are generally well preserved and indicate that the basalts were olivine-phyric with a range in olivine content from 1–30%. Drilling has intersected two areas of agglomerate in this unit; the agglomerate consists of irregular komatiitic basalt fragments, ranging in size from 2–100 mm, set in a matrix of originally glassy welded tuff with shard-like material and lapilli tuff.

Unit 3 is made up of basaltic komatiite (and some tholeiitic basalt) that is generally olivine-free and markedly lower in MgO content than the pyroxenitic basalts of Unit 2 (Williams *in prep.*). The basaltic komatiites are generally pillowed and were predominantly clinopyroxene and glass-rich basalts, many with appreciable plagioclase. Some unpillowed examples show spectacular clinopyroxene-derived spinifex texture. Although it overlies the other two units where they are developed, basalt of Unit 3 overlaps the underlying units along strike and eventually rests directly on the Sebakwian Group. Similar basalts are found, at the strike extremities of the peridotite, as wedges between the peridotite and the underlying Sebakwian Group. Further along strike, basaltic komatiites of Unit 3 interfinger with, and give way to typical tholeiitic basalts that also rest directly on the Sebakwian Group.

Although five areas of mineralization have been located (from the south northwards, Damba South, Silwane, Damba, Flow and Fibre: Fig. 3), Silwane and Damba are the only two investigated in sufficient detail to outline ore zones. A variety of types of mineralization can be recognized, including several disseminated types, blebs, schlieren and massive or vein sulfide, but the disseminated and bleb varieties

predominate. The deposits are in many ways similar to the Otter Shoot at Kambalda (Keele & Nickel 1974).

The distribution of mineralization in the Damba–Silwane area is shown in the strike and dip sections in Figure 4. At Silwane, mineralization occurs as a well-defined concentration in the lower part of the peridotite and appears confined to a basin-like depression in the footwall about 500 m in diameter. The mineralization itself is a broadly discus-shaped body up to 75 m thick at the centre but with thickness, grade and predictability falling off rapidly towards the margins. It is associated with a pronounced thickening of the host peridotite and thus with serpentinites rather than talc-carbonate rocks. The mineralization is typically patchy, with interlayered mineralized and barren peridotite quite common, particularly on the hanging-wall side of the orebody. Although mineralization can usually be correlated from one drillhole to another, the zones in adjacent drillholes are commonly not at the same stratigraphic level within the peridotite. Below the centre part of the footwall depression two drillholes have intersected a 20–30 m thick, well-mineralized peridotite body some 20 m into the footwall sedimentary rocks (Fig. 4, section EF). This small peridotite body is interpreted as a pipe-like feeder to the overlying peridotite.

The principal mineralization at Damba (Fig. 4, sections AB and GH) is located toward the centre part of the peridotite. In dip section (GH in Fig. 4) this central mineralization, typically of the bleb type, thins rapidly with depth, giving way to footwall disseminated mineralization which is confined to another, but much smaller, depression in the footwall.

The disseminated sulfide is a typical matrix-type mineralization in that most of the sulfide occurs in the interstices between the completely serpentinitized olivine crystals. The small-scale distribution of this type of mineralization is characteristically patchy and it most commonly occurs as irregular ovoid patches (2–5 cm in diameter) of matrix sulfide surrounded by barren peridotite. Only rarely does the sulfide completely fill the interstices between the olivines.

In the bleb- or globule-style of mineralization individual blebs vary in diameter from 2–20 mm and on average contain about 80% sulfide. In form they range from small, well-defined spheres to larger oblate spheroids, becoming less sharply defined with increasing size. They are associated with what appear to be chlorite- or carbonate-filled amygdaloids of similar size and shape. In some examples the bottom half is

filled with sulfide and the top half with carbonate or chlorite. Similar structures in the Otter Shoot at Kambalda have been interpreted as immiscible sulfide droplets (Keele & Nickel 1974, Keele 1975) or as amygdale fillings (Willett 1975). The Damba examples require further study but are here regarded as the sulfur-rich phase associated with primary vesiculation of the ultramafic liquid.

Sulfide veins up to 3 cm wide also occur sporadically in the peridotite and are invariably rich in magnetite. Massive sulfides are seldom found in significant amounts but thin zones (up to 20 cm in thickness) do occur at the footwall contact in some drillholes. It is quite possible that some of these contact zones are thick veins rather than actual massive sulfide accumulations. Other types of mineralization include a wide range of schlieren styles that seem to result from local remobilization of disseminated or bleb material during shearing associated with talc-carbonate alteration.

Weak mineralization, as irregular blebs, patches or veins, also extends into the footwall sedimentary rocks in some places, particularly at Flow and to a lesser extent at Silwane. This mineralization does not penetrate further than about 10 m from the peridotite and is most common in the chert that generally terminates the sedimentary series.

The principal sulfide minerals are pentlandite, millerite and pyrite with widespread minor chalcopyrite, sporadic but locally abundant violarite and pyrrhotite and traces of vallerite, gersdorffite and chalcocite (Hendriks 1974). Ni:Cu ratios average about 15:1, as is typical of nickel deposits associated with Archean ultramafic rocks (Naldrett 1973). A number of correlations can be made between differing sulfide assemblages, styles of mineralization and host-rock type although studies of the ore to date are preliminary. Two types of assemblage seem to be developed though there are exceptions and gradations between them (Hendriks 1974). The first is a *millerite-magnetite* type with relatively minor amounts of pentlandite and pyrite and the second is a *pentlandite-rich* type with a high pyrite or pyrrhotite content and less magnetite. Violarite occurs in both types and is in most cases an alteration product of either millerite or pentlandite. Magnetite occurs in three forms: as magnetite rims on chromite that is quite separate from the sulfide association; as primary magnetite forming an intrinsic part of the sulfide assemblage and as secondary magnetite that is related to serpentinization.

In the disseminated and vein sulfide ores there

is a good correlation of the millerite-magnetite type with a serpentinite host rock and of the pentlandite type regardless of host rock. Sulfides contacts between serpentinite and talc-carbonate units, as well as between the respective ore types, are generally abrupt. In contrast, the bleb or globule type of ore is almost invariably of the pentlandite type regardless of host rock. Sulfides in the footwall sediments appear to be of the pentlandite type.

A further generalization can be made in that disseminated sulfide in talc-carbonate rocks is texturally more variable and shows clear evidence of at least local remobilization. It is also of lower and more erratic grade than disseminated ore in an adjacent serpentinite. There is also a preferential association of sulfide and carbonate in the talc-carbonate rocks, and chlorite rims on the sulfides are common.

Although talc-carbonate alteration seems to have produced a more sulfur-rich (or nickel-poor) sulfide assemblage from the finely disseminated ore in the serpentinites, it does not seem to have had any effect on the sulfide blebs. This may be a result of the widely differing surface areas of the sulfide assemblages in the two types. Because of pervasive serpentinization it has not been possible to assess the effects of the serpentinization process itself on primary sulfide assemblage. The situation now is that the sulfides found in blebs (be they amygdales or immiscible droplets) are markedly sulfur-rich assemblages (pentlandite-pyrite-pyrrhotite) compared with the spatially associated, but usually stratigraphically lower, disseminated millerite-magnetite assemblage, which is relatively sulfur-deficient and of higher nickel tenor.

### *Shangani*

The Shangani nickel deposit (Philpott 1975, Viljoen *et al.* 1976) is situated about 35 km east-southeast of the Damba deposits in a separate greenstone belt, the geology of which (Fig. 2), has been documented by Harrison (1969).

Viljoen *et al.* (1976) have recently described the geology and mineralization of the deposit; there is a marked similarity between the stratigraphic successions in which the Damba and Shangani deposits are situated.

At Shangani, Viljoen *et al.* (1976) recognize the following stratigraphy in the mine area: *Esmyangene Formation* (at the base): acid to intermediate tuffs terminated by a pyritic shale, intruded by a large layered complex of peridotite, harzburgite, pyroxenite and gabbro; *Makwe Formation*: peridotite and pyritic carbonaceous

shale overlain by magnesium-rich metabasalts; *Ensangu Formation*: massive and pillowed metabasalts. Viljoen *et al.* (1976) place the contact between the Sebakwian and Bulawayan Groups at the Makwe-Ensangu Formation boundary; however, as this contact is actually within a volcanic sequence, it seems more reasonable to place it between the Esmyangene and Makwe Formations where mafic volcanism actually began. The Bulawayan Group thus begins here with the peridotite unit (= Unit 1 at Damba), with associated pyritic shales and overlying magnesium-rich basalts (= Unit 2 at Damba) of the Makwe Formation followed by the basalts and basaltic komatiites (= Unit 3 at Damba) of the Ensangu Formation (Fig. 5).

The mineralized complex at Shangani (Viljoen *et al.* 1976) lies within the Esmyangene Formation and is a trench-like peridotite body (mushroom-shaped in cross section) that is at least 1.7 km long (down dip) with the neck cutting across the regional stratigraphy (Fig. 5). The ore is predominantly disseminated and is a typical pyrrhotite-pentlandite assemblage occurring on the stratigraphically flat-lying flanking parts of the complex (Fig. 5, section CD). The downward extension of the stem of the complex

appears to be cut off by the large layered body that intrudes the Esmyangene Formation. Upward within the complex (Fig. 5, sections AB and CD) serpentinite is interlayered with amphibolite and some carbonaceous shales.

Viljoen *et al.* (1976) regard the complex as intrusive, emplaced into, or close to, an acid volcanic vent. This author prefers to interpret the complex itself as a volcanic neck that developed in the following way. It has a trench- or fissure-like form, with unlayered peridotite in the stem and in the lower part of each lobe (Fig. 5, section CD). This passes upward into a typical extrusive alternation of magnesium-rich basalt, some of which has spinifex-style textures, and more peridotite, in places with sedimentary interlayers between units. Sulfide liquid suspended in the initial peridotite pulse was swept onto, or left behind on, the flat-lying, flanking sections of the complex. The actual site or sites of ultramafic volcanism would have migrated along the trench with time. After the initial development of the mineralized complex, a pause in ultramafic volcanic activity, or its migration along the fissure, allowed further accumulation of felsic tuffaceous material from ongoing but waning acid volcanism. Renewed

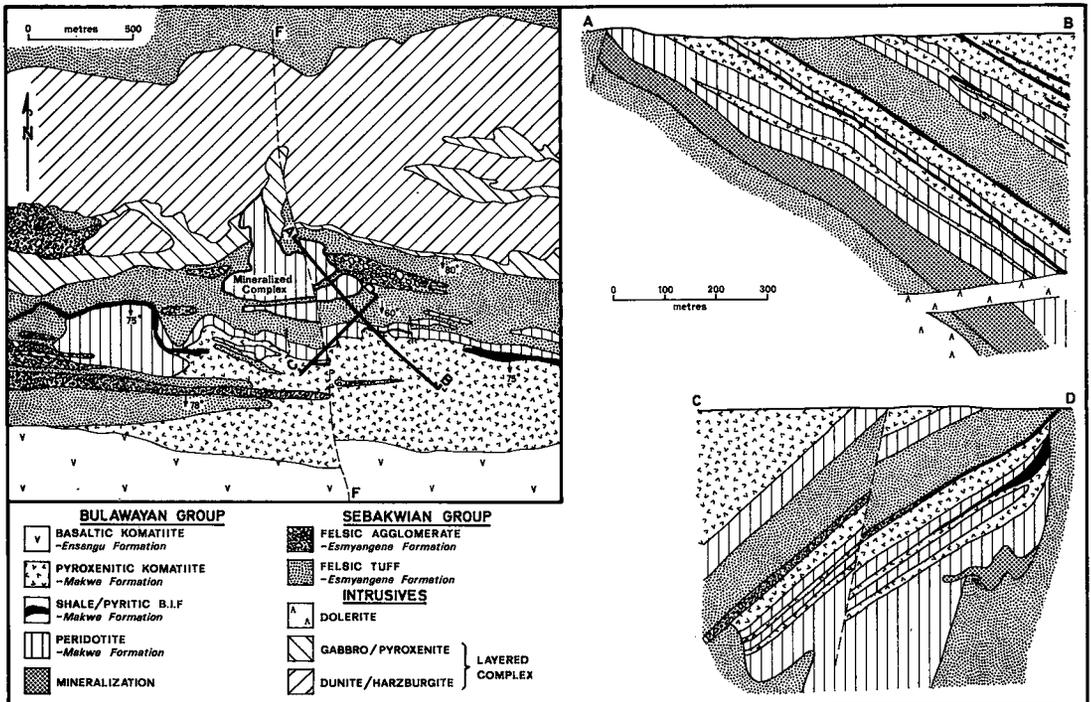


FIG. 5. Simplified plan and sections for Shangani. Modified from Viljoen *et al.* (1976).

ultramafic volcanism, yielding a peridotite with finer grained suspended olivine crystals than previously, initiated the Bulawayan proper with the first part of the Makwe Formation. This peridotite (= Unit 1 at Damba) probably issued from other sites along the fissure zone and was immediately followed first by the pyroxenitic komatiite lavas (= Unit 2 at Damba) that make up the rest of the Makwe Formation, and then by the thick sequence of basaltic komatiites and basalts of the Ensangu Formation (= Unit 3 at Damba).

Thus the mineralized complex can be regarded as the first tentative stage of Bulawayan Group ultramafic volcanism in a zone of crustal weakness where Viljoen *et al.* (1976) have recognized that felsic volcanism had been, or still was, in progress. Viljoen *et al.* (1976) have also demonstrated that this zone acted as a vent for the overlying volcanic rocks. Thus the mineralization itself is found on the horizontal or kink-structured sites flanking a vertical conduit; the interpretation outlined above shows again the close link that exists in this region between nickel mineralization and the first volcanic event in the Bulawayan Group.

#### *Epoch*

The Epoch nickel mine is situated 85 km south of Shangani (Fig. 2). Although there is no published account of the deposit, several points of interest have been ascertained from available maps (Ferguson 1934) and the present investigation. Firstly, the deposit is also situated at or near the continuation of the contact between the Sebakwian and Bulawayan Groups. Secondly, like Shangani, it appears to be associated with a cross-cutting peridotite complex (Viljoen *et al.* 1976, p. 93) immediately above an ultramafic-dominated layered sill intruded into the upper part of the Sebakwian Group. Thirdly, the Bulawayan Group lavas that stratigraphically overlie the deposit contain a significant komatiitic basalt component (Fig. 2). It is understood that the main sulfides are millerite and pentlandite as found at Damba. Thus a cross-cutting peridotite at or near the base of Bulawayan Group komatiitic volcanism is a feature of another deposit in the region.

#### *Selukwe*

Another nickel prospect occurs in the Selukwe belt (Fig. 2) and again there is no published account of the occurrence. However, the deposit is also located near the contact between the Sebakwian Group and peridotites apparently

intrusive into the Bulawayan Group. Descriptions of the general geology and petrology by Stowe (1968) suggest that komatiitic volcanic rocks are also developed in the area.

#### *Hunters Road*

The Hunters Road nickel deposit (Brand 1976) is situated 80 km northeast of Shangani (Fig. 2), on the east limb of the Gwelo syncline in what appears to be a cross-cutting serpentinite body. In this case the host serpentinite cuts through a banded iron-formation lying at the contact between acid to intermediate volcanic rocks below, and pillowed tholeiitic basalts above (Macgregor 1937, Tyndale-Biscoe 1949, Harrison 1970). Brand (1976 and oral presentation, Salisbury) stated that disseminated sulfide mineralization occurs in a serpentinite intruded along a tear fault and suggested that both intrusive and extrusive ultramafic rocks may be represented. He also noted that layers showing spinifex texture are developed in the body and that it contains large xenoliths of greenstone, banded iron-formation and acid volcanic rocks.

At first glance this deposit would not appear to be at the same regional contact as the other deposits. However, the greenstone belt extending northwesterly from Gwelo is synclinal, with a succession on the west limb of Sebakwian Group schists overlain in turn by andesite and Bulawayan Group mafic volcanic rocks (Fig. 2). On the east limb, where the nickel deposit is located, a similar but far thicker succession of andesite is present and overlain by tholeiitic basalts, but there is no evidence of a Sebakwian-type sequence at the base. Structural information in the Sebakwian Group on the west limb suggests that the andesites represent the first volcanism of the Bulawayan Group in this area. Therefore, the Hunters Road deposit does occur at a stratigraphic position marking the beginning of Bulawayan Group mafic volcanism as is the case with the other deposits. In this case, however, the mafic volcanism that follows is tholeiitic and not komatiitic.

#### *Lower Gwelo*

The west limb of the Gwelo syncline has the Sebakwian Group at the base and it here consists of quartz-mica schists, quartzofeldspathic sedimentary units, banded iron-formations and serpentinites (Macgregor 1937, Tyndale-Biscoe 1949). It is overlain in turn by a thin but continuous andesite unit, a typical Damba-Shangani komatiite sequence, pillowed tholeiitic basalts, banded iron-formations and

well-preserved grits and conglomerates that make up the synclinal core.

The komatiitic sequence consists of peridotitic and pyroxenitic komatiites at the base, overlain by basaltic and spinifex-textured "andesitic" komatiite lavas (Williams *in prep.*). Disseminated nickel sulfide mineralization is present in the ultramafic unit at the base of the volcanic pile but has yet to be fully evaluated. Again, mineralization is at the same regional contact.

### Noel

The Noel nickel arsenide deposit (Phaup 1933) is in the Lower Gwanda belt (Fig. 2) and has been known since 1928. The deposit consists principally of chloanthite and niccolite associated with calcite and silicate veinlets in a fault zone in an actinolitic serpentinite. Although clearly hydrothermal, the deposit is also within a komatiite succession which, in this case, consists of a complex interlayering of basaltic-textured peridotites (Phaup 1933) and basaltic and pyroxenitic komatiites.

## DISCUSSION

Many features of the Damba nickel deposits point to a close relationship of ore with early peridotitic volcanism. The presence of amygdaloidal spinifex-textured units, probable flow-top breccias and ultramafic tuffs within the host peridotite all indicate an extrusive origin. A possible feeder conduit (or vent) is recognized under the Silwane mineralization and the presence of an agglomerate zone 175 m above it within the overlying pyroxenitic komatiites (Unit 2) adds support to the idea of a vent in this locality.

The mineralization occurs as blebs (at least some of which were immiscible droplets) and as disseminated matrix sulfide that has a definite appearance of being of a similar droplet style but dispersed by included olivine crystals to produce the ovoid patches of disseminated sulfide. Mineralization occurs in a thick basin-like depression or lava pool that overlies the possible feeder, which is itself concentrically mineralized with higher grade ore in the centre passing outward into lower grade ore. These factors all suggest that the sulfide is an intrinsic part of the host peridotite magma. Furthermore, the emplacement of peridotite and ore was the first event of komatiitic volcanism within the Bulawayan Group in this area.

Features of many of the other deposits suggest that similar relationships exist between

mineralization and volcanism throughout the region. Several deposits (Shangani, Epoch and Hunters Road) are in, or associated with, cross-cutting peridotite complexes at the contact between the Sebakwian and Bulawayan Groups. At Shangani the mineralized complex has the form of a fissure-filling with the trunk of the body cutting across the regional stratigraphy. This, together with the flanking position of the mineralization and overall form of the complex, suggests that it is either a magma chamber or an actual volcanic neck or vent. The latter alternative is preferred because of the interlayering of peridotite, spinifex-textured amphibolite (here regarded as komatiitic lava) and carbonaceous shale in the upper part of the complex.

The Hunters Road deposit is also in what appears to be a cross-cutting complex and large xenoliths of country rock are recorded as occurring within the serpentinite. Some of the mineralization in this deposit is in the form of small droplets like those described from Damba and supports the view that the sulfides were carried as an immiscible phase at the time of emplacement. The different types of sulfide mineralization found at Damba suggest that both sulfur-rich and sulfur-poor phases may have existed as droplets in close proximity to each other. Significantly, at least at Damba, the sulfur-rich assemblage is found within markedly amygdaloidal zones in the host peridotite.

Using the concept that sulfides were transported as an immiscible phase within an olivine crystal - ultramafic liquid mush, Naldrett (1973) has speculated on some likely relationships between ore, host and country rock. His diagrams are reproduced here in Figure 6 and show possible reconstructions of the settings for Shangani (Fig. 6, example 1 or 2) and Silwane (example 3).

As there seems to be a close association between ore and volcanism, it is useful to examine the general relationships between the various volcanic assemblages within the Bulawayan Group and thus the regional setting of the deposits. The present study has shown that komatiitic volcanic rocks are more widespread in the Rhodesian greenstone belts than indicated on existing maps. It has also shown that the simple komatiite stratigraphy described by Viljoen *et al.* (1976) at Shangani and described in detail here for the Lonely Mine belt is widespread in the region. Another example is developed on the western limb of the Gwelo belt; Bickle *et al.* (1975) and Nisbet *et al.* (1977) have described a particularly extensive succession in the Belingwe belt. These stratigraphic sequences begin

with a peridotite and pyroxenitic komatiite unit that ranges up to 1 km in thickness, followed by a thick pile (up to 7 km) of basaltic komatiite and some tholeiitic basalts. The basaltic komatiites commonly show clinopyroxene-derived spinifex texture or various textures caused by skeletal clinopyroxene crystallization. More pyroxenitic or olivine-bearing examples are intercalated with the basaltic varieties, but are not common. These komatiitic sequences have widely varying strike extents ranging from 15–80 km.

Along strike the komatiitic volcanic rocks

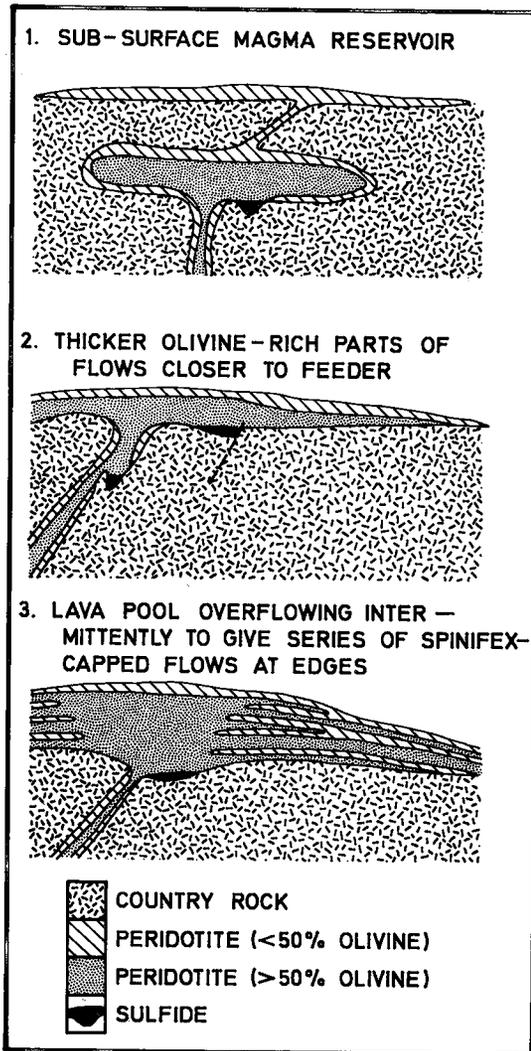


FIG. 6. Speculations on likely relationships between ore, host and country rock in nickel deposits of volcanic association by Naldrett (1973).

overlap and interfinger with apparently concomitantly extruded tholeiitic basalts. These are typically pillowed, weakly plagioclase-phyric basalts showing little of the skeletal crystallization that is usually characteristic of the komatiite suite. However, the distinction between the tholeiites and low-MgO basaltic komatiites is often difficult and some uncertainty exists at these compositions. This overlap is also apparent in their geochemistry (Williams *in prep.*) and might suggest that the two magma types result from different levels of tapping of a common magma stem. The more MgO-rich komatiitic rocks, which are the nickel sulfide hosts, would be expected to result from the deeper tapping.

Higher up in the Bulawayan Group the interlayering of volcanic types becomes more complex. In the Lonely Mine – Bulawayo belt a thick succession of andesite lavas overlies the tholeiitic and komatiitic volcanic suites and is, in turn, overlain by either more basaltic and pyroxenitic komatiites or by tholeiites. It is clear that in most of the Rhodesian greenstone belts examined during this study, the simple komatiite to tholeiite evolution proposed for other greenstone belts in southern Africa (Viljoen & Viljoen 1969) does not apply. Rather there seems to be random interlayering and overlapping of adjacent compositionally different volcanic suites throughout the succession. The clear evidence of contemporaneous or penecontemporaneous tholeiitic and komatiitic volcanism, and in some cases acid volcanism (Lonely Mine belt), is particularly important. Andesitic lavas and agglomerates can occur either before komatiitic and tholeiitic activity (Belingwe, Gwelo, Hunters Road) or after (Lonely Mine – Bulawayo, Gwanda).

In summary, six nickel deposits in the region are found at or near the same regional contact; they seem to form an integral part of the very first event of komatiitic volcanism within the Bulawayan Group. Several of the deposits lie within cross-cutting peridotite complexes that can be interpreted as volcanic necks or vents lying in sites that acted as volcanic centres both prior to, and following, peridotite-ore emplacement. The configuration of the Shangani mineralized complex suggests that the ore-bearing komatiitic volcanism was of a fissure type.

#### ACKNOWLEDGEMENTS

The permission of Johannesburg Consolidated Investment Company Limited to publish these results is gratefully acknowledged. I am indebted

to Company colleagues who have contributed to this study, particularly R. Mason, D.E. Philpott, C. Willson, D.M. Anderson and L.P. Hendriks and to R.P. and M.J. Viljoen who first introduced me to the Damba and Shangani deposits. Staff of the Rhodesia Geological Survey provided invaluable advice and comment during the regional investigation, and special thanks go to N.M. Harrison and I.D.M. Robertson. I am very grateful to I.D.M. Robertson, R. Mason, P.G. Cochran and D.L. Garnett for criticizing drafts of the manuscript. Special thanks go to my wife Gwynn for her geological help both in the field and office, to Piet Britz for his draughting and Elizabeth Vigus for typing the manuscript.

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Received August 1978; revised manuscript accepted December 1978.