

https://dspace.org/

The geology of the archaean granitoid-greenstone terrane in the vicinity of three Sisters, Barberton greenstone Belt.

Kohler, Ernest Alfred

1994
https://hdl.handle.net/10539/24354

Downloaded from a DSpace repository. https://dspace.org/

Field and microstructural observations indicate that S_d foliations throughout the synform and antiform are continuous and contemporaneous. However, the S_d fabric exhibits a markedly different geometrical relationship to each of these structures. In the Bien Venue Synform, S_d is axial planar and generally obliquely transects the primary strike and dip of the supracrustal rocks where discernable. The S_d fabric in the Stentor Antiform, on the other hand, is conformable with S_p, the Stentor pluton - schist contact, as well as the foliation seen along the plutons southeastern margin (Sections 8.3.1), but cuts across the axial trace. S_d dips away from, and is also best developed immediately adjacent to, the pluton, and diminishes in intensity eastwards over a interval of ~5 km. Microstructural relationships indicate that andalusite and chloritoid porphyroblastesis in the quartz-muscovite schists was syn- to postkinematic with respect to the foliation (Section 4.3.1). L_d stretching lineations typically pitch steeply within the S_d schistosity surfaces and define an overall subradial pattern with respect to the Stentor pluton. Strain ellipsoids are dominantly of the oblate type.

The distribution, orientation and style of the D_d structures and fabrics indicate that D_d deformation was related to the emplacement of the Stentor pluton, either as diapir or as a ballooning pluton. Salient features of diapirs and plutons that have undergone ballooning include: (1) major deformation and alteration in the wall rocks; (2) a marked increase in strain intensity with proximity to the intrusion; (3) contact-parallel foliations within the intrusion and country rocks; (4) steep radial or tangential stretching lineation patterns; and (5) porphyroblast growth which is at least in part synkinematic with respect to the aureole foliation (e.g. Schwerdtner *et al.*, 1978; Coward, 1981; Van den Eeckhout *et al.*, 1986; Bateman, 1984, 1986; Courrioux, 1987; Paterson, 1989, England, 1990; Jelsma *et al.*, 1993). Structural features within the Stentor Antiform - Bien Venue Synform pair accord well with these criteria, and there is little doubt that the formation of the D_d structures resulted from the intrusion of the Stentor pluton at 3107 Ma. This deformation was analogous in many respects to that which accompanied the emplacement of the early trondhjemite gneiss plutons along the southwestern margin

of the BGB (e.g. Anhaeusser, 1984; Kisters and Anhaeusser, 1993). Given the fact that the S_d foliation transects the axial trace of the Stentor Antiform, it may be concluded that the fabric is of a slightly younger age than the fold-forming event - i.e. the foliation was superimposed onto the fold.

The difficulties in distinguishing diapiric plutons from ballooning plutons have been discussed by England (1990) and Jelsma *et al.* (1993). According to England (1990, p. 931), diapiric emplacement " ... *can only be proven beyond doubt where it is possible to demonstrate vertical uplift of country rocks in excess of the vertical thickness of the intrusion*". This necessitates detailed information regarding the three-dimensional geometry of the intrusive body and its enclosing successions. In the absence of such information, England (1990) and Jelsma *et al.* (1993) suggested that radial stretching lineation patterns, kinematic criteria showing a pluton-up movement sense, and pre- to synkinematic porphyroblast growth are typical of diapirism, while tangential linear fabric patterns and syn- to postkinematic porphyroblastesis are consistent with pluton ballooning.

Although structural features within the Stentor Antiform and Bien Venue Synform accord best with those of diapiric plutons, it is possible that the Stentor pluton underwent late-stage ballooning. This is likely to have occurred when one considers that the granitoid diapir was emplaced into silicic country rocks little different in density from itself. A decrease in the density contrast between the diapir and the enclosing rocks would have lessened the buoyancy forces, resulting in the cessation of movement at the top of the diapir (Brun and Pons, 1981; England, 1990). This, in turn, would have led to the inflation of the pluton as the tail-end of the diapir continued to rise (Figure 9.19).

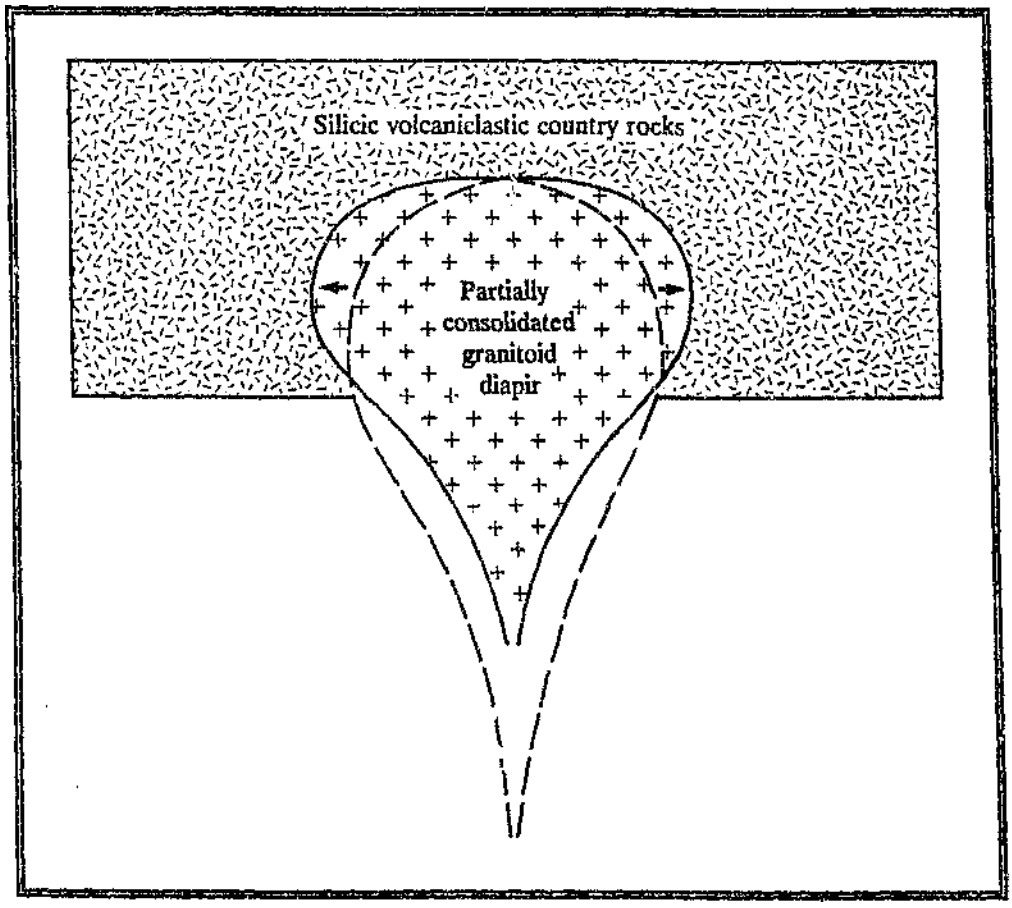

Figure 9.19 Schematic diagram illustrating a possible mechanism for late-stage inflation of a diapir (modified after the ballooning mongolfiere model of Brun and Pons, 1981). Cessation of ascent in the upper parts of the diapir in response to a decrease in the magnitude of the buoyancy forces results in ballooning as magma in the lower parts of the diapir continues to rise.

The following sequence of events leading to the formation and modification of the D_d structures is envisaged:

- North-northwest-directed compression led to the formation of the early D_m structures, including the Three Sisters and American Synclines, and the American and Barite Faults, which originally had easterly or east-northeasterly trends (Section 9.3.1).

- This was followed at 3107 Ma by the forceful intrusion of the Stentor pluton as a hot, partially consolidated diapir. The intrusion of the pluton led to the folding of the Barite Fault, the refolding of rocks in the extreme western part of the Three Sisters Syncline, the reorientation of the American Syncline and associated bounding fault, and gave rise to the Stentor Antiform - Bien Venue Synform couple.

- Concomitant development of a penetrative foliation in the crystallized parts of the pluton and a time-delayed foliation with associated lineation in the country rocks. Extensive contact metamorphism - metasomatism of the silicic metavolcanic rocks resulted in the hydrolysis of feldspar to muscovite, as well as the synkinematic growth of andalusite and, to a lesser extent, chloritoid (Section 5.2.1.1). Concomitant intrusion of he numerous quartz ± tourmaline veins and granitoid apophyses that occur parallel to the aureole foliation (Sections 4.3.8 and 8.3.1).

- Consolidation of the pluton. Thermal relaxation after intrusion led to the postkinematic growth of chloritoid and some andalusite, which was followed, in the waning stages, by the partial retrogression of these phases to chlorite and pyrophyllite, respectively (Section 5.2.1.2).

- Late-phase D_m shearing along the Revolver and Stentor - Overton Faults eliminated the southern extremities of the Bien Venue Synform as well as portions of the pluton (Section 9.3.1).

9.3.3 D_{final}

Field evidence suggests that the B_f structures are steeply dipping, oblique- and dip-slip faults. However, the sense of movement across these faults and, hence, the nature of the stresses involved in their formation, remains unclear. Nonetheless, the writer suspects that most represent normal faults.

10. SUMMARY AND CONCLUSIONS

The principal conclusions and suggestions of this study are summarized below.

10.1 Onverwacht Group

The Onverwacht rocks in the Three Sisters region consist of a variable assemblage of fine-grained basic-to-ultrabasic schists and amphibolites, with minor serpentinite and silicic schist. They are believed to form part of the Tjakastad Subgroup, specifically the Theespruit Formation. Relic structures are seldom preserved, so that the primary characteristics of the rocks cannot readily be determined. Nonetheless, available textural evidence suggests that they were derived mainly from volcanic-volcaniclastic protoliths. Chemical analyses suggest that the precursor suite ranged in composition from komatiite and komatiitic basalt through to basalt and dacite/rhyodacite. Coarse-textured lithologies, believed to represent metamorphosed gabbros and pyroxenites, also crop out in places. These rocks are considered to form an integral part of the Onverwacht succession, and are interpreted as subvolcanic intrusions.

Peak metamorphism of the Onverwacht rocks accompanied the intrusion of the Nelspruit batholith, and attained medium-grade in peripheral zones flanking the granitoids. Late-stage retrograde processes, ascribed to the influx of CO_2-bearing fluids either during the waning stages of contact metamorphism or associated with subsequent deformation of the supracrustal belt, have, however, led to the localized downgrading of the prograde assemblages.

10.2 Fig Tree Group

The Fig Tree Group in the northeastern sector of the BGB comprises three formations, viz., the Sheba, Belvue Road and Bien Venue Formations. Variably altered greywacke - shale - BIF assemblages that accumulated in a relatively deep-water

environment, dominate the Sheba and Belvue Road Formations. Stratigraphically overlying the latter unit is a sequence of silicic schists, with volumetrically minor intercalations of basic-ultrabasic schist, phyllite, chert and cherty dolomite. These rocks have previously been considered to constitute part of the Theespruit Formation, but have been assigned by the writer to the Bien Venue Formation. U-Pb isotopic studies on zircons extracted from a sample collected near the top of this unit yielded an age of 3256 ±1 a (2σ). This age is ~200 Ma younger than the most recent high precision age estimates for the lower portions of the Onverwacht Group, and some 30 Ma older than age determinations on the rocks of the Schoongezicht Formation, precluding correlation of the Bien Venue rocks with either of these formations.

Due to severe alteration and deformation, it is not possible to determine the precise primary characteristics of the silicic schists. However, relic textures such as feldspar and bipyramidal quartz phenocrysts, and less commonly, conglomerate clasts composed of recrystallized chert and altered volcanic rock, attest to original volcanic / epiclastic protoliths. The schists also host Kuroko-like massive sulphide mineralization which is known to form in deep-marine settings. Thus, it is suggested that the rocks of the Bien Venue Formation, like those of the underlying Sheba and Belvue Road Formations, were mainly deposited in a deep-water environment.

Two main varieties of silicic schist are distinguishable on the basis of geochemistry and metamorphic mineralogy. These include: (1) quartz-muscovite (± andalusite ± pyrophyllite ± chlorite ± chloritoid) schists which are typically characterised by high SiO_2 (> 72 wt %) and low CaO (≤ 0.3 wt %), Na_2O (< 0.5 wt %) and Sr (≤ 40 ppm) contents; and (2) biotite-oligoclase (± chlorite ± carbonate ± quartz) schists which have lower SiO_2 concentrations (66 - 70 wt %) and elevated CaO (≥ 0.9 wt %), Na_2O (≥ 3.6 wt %) and Sr (≥ 65 ppm) abundances compared to the quartz-muscovite schists. The quartz-muscovite schists which constitute the dominant lithology encountered in the Bien Venue Formation, were probably derived from dacitic-

to-rhyodacitic precursors, and are similar to rocks found within the Theespruit Formation. The biotite-oligoclase schists, by contrast, appear to have had andesitic or dacitic primary compositions, and resemble lithologies comprising the Schoongezicht Formation.

Petrographic and geochemical data for the quartz-muscovite schists suggests that their primary characteristics have been radically changed during alteration. Mineralogical transformations were dominated by the extensive hydrolysis of primary feldspar to muscovite, followed by the partial alteration of muscovite to andalusite, chlorite and biotite. Mineral assemblages and paragenesis in areas away from the immediate contact zone with the Stentor pluton, which intrudes the schists, are indicative of low-grade conditions. Evaluation of the metamorphic conditions closer to the granitoid contact is hampered by a lack of suitable indicator minerals, but probably attained medium-grade, as indicated by the adjacent amphibolite-grade metavolcanics within the Onverwacht Group.

The alteration of the quartz-muscovite schists led to the marked depletion of Na, Ca and Sr, and also decoupled the LFSE's from the HFSE's. The LFSE distributions are primarily controlled by secondary muscovite, whereas the distribution of the HFSE's appears to reflect complexities associated with allovolumetric alteration of a compositionally heterogeneous precursor suite.

Comparison of the immobile element concentrations of the Bien Venue Formation rocks with modern volcanic suites indicates that they are characterised by a distinct arc-like geochemical signature. This suggests that the formation represents a period of arc volcanic activity terminating Fig Tree Group deposition in the northeastern sector of the BGB.

10.3 Moodies Group

The Moodies Group comprises an up to 2200 m thick succession of conglomerates, quartzites and subordinate siltstones which unconformably or paraconformably overlie a diverse variety of lithologies belonging to both the Fig Tree and Onverwacht Groups. Correlation of the siliciclastic assemblage with any particular formation of the Moodies Group as defined by SACS (1980) is not possible owing to marked lateral and vertical lithological variations. Nonetheless, the overall character of the rocks indicates that they are comparable to Moodies lithologies elsewhere in the BGB, and that they are the product of sedimentation in a high-energy, shallow-marine to subaerial depositional environment. The unusual coarseness and thickness of some conglomerate units along the northern flank of the BGB is not compatible with sedimentological models invoking a southerly source terrane for the Group (e.g. Eriksson, 1977, 1979, 1980b; Jackson *et al.*, 1987), but appears to conform with the results of recent investigations by Heubeck and Lowe (1993, 1994) who suggested that some Moodies sediments were derived from a northerly provenance area.

10.4 Granitoid rocks and late-stage intrusives

The western part of the region is underlain by a diverse variety of massive-to-gneissic granitoids, some of which have previously been considered to constitute part of the Stentor trondhjemite pluton. Field and geochemical work during the course of the present investigation indicates, however, that the Stentor pluton consists of equigranular-textured granitoid rocks that range in composition from granodiorite to adamellite. These rocks are comparable to those found within the Hebron and Berlin plutons. The latter bodies constitute a textural phase of the 3.1 Ga Nelspruit batholith, and it is suggested that the Stentor pluton also forms an integral part of the batholith. This conclusion is compatible with the results of recent high-precision isotopic studies indicating that the Stentor and Hebron plutons, as well as the Nelspruit Porphyritic Granite, are contemporaneous within error. Trace element modelling suggests that compositional

variations within the Stentor pluton are the result of 10 - 75% fractional crystallization of a quartz + plagioclase + K- feldspar + biotite cumulus assemblage, consistent with previous chemical models that have been proposed for the Nelspruit batholith.

Rocks of the Nelspruit Migmatite and Gneiss Terrane crop out to the north and west of the Stentor pluton. The gneisses display a wide range of compositions from trondhjemite-to-granite (*sensu stricto*), but are typically potassic, in places containing abundant K-feldspar megacrysts.

Late-stage magmatic activity in the region is manifest mainly in the form of diabase dykes, of presumed Early Proterozoic age, that intrude all pre-existing supracrustal and granitoid lithologies.

10.5 Structure

The structural architecture of the northeastern sector of the BGB is dominated by a series of northeast-trending, upright or northwesterly verging folds, such as the Three Sisters, Big Buffalo and Hlambanyathi Synclines, as well as similarly striking, subvertical or southeast-dipping faults, including the Barbrook, Revolver and Scotsman Faults. The latter structures are believed to have resulted mainly from reverse dip-slip displacement, with comparatively minor strike-slip movement. The major folds post-date the Moodies Group, but pre-date the granitoids of the Nelspruit batholith. The faulting outlasted the folding as well as the emplacement of the batholith.

Deformation of a more localized nature accompanied the diapiric emplacement of the Stentor pluton, and gave rise to two large-scale folds, namely the Stentor Antiform and the Bien Venue Synform, during the regional deformation event. The final tectonic event in the region led the formation of minor, northwest- to northeast-striking, oblique-slip normal faults.

10.6 Economic geology

The rocks of the region host deposits of gold, antimony, iron and talc, none of which is currently being exploited. Subeconomic exhalative-type massive sulphide mineralization occurs associated with silicic schists of the Bien Venue Formation. Geochemical comparison of these schists with silicic metavolcanic sequences hosting major VHMS deposits in the Superior Province of Canada suggests that their potential for economic base-metal mineralization is low.

11. REFERENCES

Abbott, D.H., and **Hoffman, S.E.** (1984). Archaean plate tectonics revisited. 1: Heat flow, spreading rate, and the age of the subducting oceanic lithosphere and their effects on the origin and evolution of continents. *Tectonics*, **3**, 429 - 448.

Aggarwal, P.K., and **Nesbitt, B.E.** (1987). Pressure and temperature conditions of metamorphism in the vicinity of three massive sulfide deposits, Flin Flon - Snow Lake belt, Manitoba. *Can. J. Earth Sci.*, **24**, 2305 - 2315.

Albarede, F., and **Bottinga, Y.** (1972). Kinetic disequilibrium in trace element partitioning between phenocrysts and host lava. *Geochim. cosmochim. Acta*, **36**, 141 - 156.

Allen, R.L. (1988). False pyroclastic textures in altered silicic lavas, with implications for volcanic-associated mineralization. *Econ. Geol.*, **83**, 1424 - 1446.

Allen, R.L. (1992). Reconstruction of the tectonic, volcanic, and sedimentary setting of strongly deformed Zn-Cu deposits at Benambra, Victoria. *Econ. Geol.*, **87**, 825 - 854.

Anhaeusser, C.R. (1963). *The geology of the Lily syncline and portion of the Eureka syncline between Sheba Siding and Louw's Creek Station, Barberton Mountain Land*. M.Sc. thesis (unpubl.), Univ. Witwatersrand, Johannesburg, 150 pp.

Anhaeusser, C.R. (1965). Wrench faulting and its relationship to gold mineralization in the Barberton Mountain Land. *Inform. Circ. Econ. Geol. Res. Unit, Univ. Witwatersrand, Johannesburg*, **24**, 25 pp.

Anhaeusser, C.R. (1969). *The stratigraphy, structure and gold mineralization of the Jamestown and Sheba Hills areas of the Barberton Mountain Land*. Ph.D. thesis (unpubl.), Univ. Witwatersrand, Johannesburg, 332 pp.

Anhaeusser, C.R. (1972). The geology of the Jamestown Hills area of the Barberton Mountain Land, South Africa. *Trans. geol. Soc. S. Afr.*, **75**, 225 - 263.

Anhaeusser, C.R. (1973). The evolution of the early Precambrian crust of South Africa. *Phil. Trans. Roy. Soc. Lond.*, **A273**, 359 - 388.

Anhaeusser, C.R. (1975). Precambrian tectonic environments. *Ann. Rev. Earth Planet. Sci.*, **3**, 31 - 53.

Anhaeusser, C.R. (1976a). Archean metallogeny in southern Africa. *Econ. Geol.*, **71**, 16 - 43.

Anhaeusser, C.R. (1976b). The geology of the Sheba Hills area of the Barberton Mountain Land, South Africa, with particular reference to the Eureka Syncline. *Trans. geol. Soc. S. Afr.*, 79, 253 - 280.

Anhaeusser, C.R. (1978). On an Archaean marundite occurrence (corundum-margarite rock) in the Barberton Mountain Land, Eastern Transvaal. *Trans. geol. Soc. S. Afr.*, 81, 211 - 218.

Anhaeusser, C.R. (1980). A geological investigation of the Archaean granite-greenstone terrane south of the Boesmanskop syenite pluton, Barberton Mountain Land. *Trans. geol. Soc. S. Afr.*, 83, 93 - 106.

Anhaeusser, C.R. (1981a). Geotectonic evolution of the Archaean successions in the Barberton Mountain Land, South Africa, 137 - 160. *In:* Kröner, A., Ed., *Precambrian Plate Tectonics.* Elsevier, Amsterdam, 781 pp.

Anhaeusser, C.R. (1981b). The relationship of mineral deposits to early crustal evolution. *75th Anniversary Volume, Econ. Geol.*, 42 - 62.

Anhaeusser, C.R. (1984). Structural elements of Archaean granite-greenstone terranes as exemplified by the Barberton Mountain Land, southern Africa, 57 - 78. *In:* Kröner, A., and Greiling, R., Eds., *Precambrian Tectonics Illustrated.* E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 419 pp.

Anhaeusser, C.R. (1986a). Archaean gold mineralization in the Barberton Mountain Land, 113 - 154. *In:* Anhaeusser, C.R., and Maske, S., Eds., *Mineral Deposits of Southern Africa*, 1. Geol. Soc. S. Afr., 1020 pp.

Anhaeusser, C.R. (1986b). The Lily Gold Mine, Barberton greenstone belt: geology, mineralogy and supergene gold enrichment, 187 - 196. *In:* Anhaeusser, C.R., and Maske, S., Eds., *Mineral Deposits of Southern Africa*, 1. Geol. Soc. S. Afr., 1020 pp.

Anhaeusser, C.R., and **Robb, L.J.** (1981). Magmatic cycles and the evolution of the Archaean granitic crust in the Eastern Transvaal and Swaziland. *Spec. Publ. geol. Soc. Aust.*, 7, 457 - 467.

Anhaeusser, C.R., and **Robb, L.J.** (1983). Geological and geochemical characteristics of the Heerenveen and Mpuluzi batholiths south of the Barberton greenstone belt and preliminary thoughts on their petrogenesis. *Spec. Publ. geol. Soc. S. Afr.*, 9, 131 - 151.

Anhaeusser, C.R., and **Viljoen, M.J.** (1986). Archaean metallogeny of South Africa, 33 - 42. *In:* Anhaeusser, C.R., and Maske, S., Eds., *Mineral Deposits of Southern Africa*, 1. Geol. Soc. S. Afr., 1020 pp.

Anhaeusser, C.R., Mason, R., Viljoen, M.J., and **Viljoen, R.P.** (1969). A reappraisal of some aspects of Precambrian shield geology. *Bull. geol. Soc. Amer.*, **80**, 2175 - 2200.

Anhaeusser, C.R., Robb, L.J., and **Viljoen, M.J.** (1983). Notes on the provisional geological map of the Barberton greenstone belt and surrounding granitic terrane, Eastern Transvaal and Swaziland (1:250 000 colour map). *Spec. Publ. geol. Soc. S. Afr.*, **9**, 221 - 223.

Aque, J.J. (1991). Evidence for major mass transfer and volume strain during regional metamorphism of pelites. *Geology*, **19**, 855 - 858.

Arculus, R.J. (1987). The significance of source versus process in the tectonic controls of magma genesis. *J. Volcanol. Geotherm. Res.*, **32**, 1 - 12.

Arculus, R.J., and **Powell, R.** (1986). Source component mixing in the regions of arc magma generation. *J. Geophys. Res.*, **B91**, 5913 - 5926.

Armstrong, R.A., Compston, W., De Wit, M.J., and **Williams, I.S.** (1990). The stratigraphy of the 3.5 - 3.2 Ga Barberton greenstone belt revisited: a single zircon ion microprobe study. *Earth Planet. Sci. Lett.*, **101**, 90 - 106.

Arndt, N.T. (1983). Role of a thin, komatiite-rich oceanic crust in the Archean plate-tectonic process. *Geology*, **11**, 372 - 375.

Barker, F. (1979). Trondhjemite: definition, environment and hypotheses of origin, 1 - 12. *In:* Barker, F., Ed., *Trondhjemites, Dacites and Related Rocks*. Elsevier, Amsterdam, 659 pp.

Barley, M.E. (1992). A review of Archean volcanic-hosted massive sulfide and sulfate mineralization in Western Australia. *Econ. Geol.*, **87**, 855 - 872.

Barley, M.E. (1993). Volcanic, sedimentary and tectonostratigraphic environments of the ~3.46 Ga Warrawoona Megasequence: a review. *Precambrian Res.*, **60**, 47 - 67.

Barley, M.E., Blake, T.S., and **Groves, D.I.** (1992). The Mount Bruce Megasequence Set and eastern Yilgarn Craton: examples of late Archaean to early Proterozoic divergent and convergent craton margins and controls on mineralization. *Precambrian Res.*, **58**, 55 - 70.

Barrett, T.J., Cattalani, S., Chartrand, F., and **Jones, P.** (1991). Massive sulfide deposits of the Noranda area, Quebec. II. The Aldermac Mine. *Can. J. Earth Sci.*, **28**, 1301 - 1327.

Barton, C.M. (1982). Geology and mineral resources of northwest Swaziland (Barberton greenstone belt). *Bull. geol. Surv. Swaziland*, **10**, 97 pp.

Barton, J. M., Jr., Robb, L.J., Anhaeusser, C.R., and **Van Nierop, D.A.** (1983). Geochronologic and Sr-isotopic studies of certain units in the Barberton granite-greenstone terrane, South Africa. *Spec. Publ. geol. Soc. S. Afr.* , **9**, 63 - 72.

Bateman, R. (1984). On the role of diapirism in the segregation, ascent and final emplacement of granitoid magmas. *Tectonophysics*, **110**, 211 - 231.

Bateman, R. (1986). On the role of diapirism in the segregation, ascent and final emplacement of granitoid magmas - reply. *Tectonophysics*, **127**, 167 - 169.

Bell, T.H., and **Cuff, C.** (1989). Dissolution, solution transfer, diffusion versus fluid flow and volume loss during deformation/metamorphism. *J. Metamorphic Geol.*, **7**, 425 - 447.

Bell, T.H., Rubenach, M.J., and **Fleming, P.D.** (1986). Porphyroblast nucleation, growth and dissolution in regional metamorphic rocks as a function of deformation partitioning during foliation development. *J. Metamorphic Geol.*, **4**, 37 - 67.

Berge, J.W. (1981). Recent investigations of two quartz porphyroidal rock - volcanogenic massive sulfide occurrences. *Econ. Geol.*, **76**, 1211 - 1216.

Bernier, L.R., and **MacLean, W.H.** (1989). Auriferous chert, banded iron formation, and related volcanogenic hydrothermal alteration, Atik Lake, Manitoba. *Can. J. Earth Sci.*, **26**, 2676 - 2690.

Berry, R.F., Huston, D.L., Stolz, A.J., Hill, A.P., Beams, S.D., Kuronen, U., and **Taube, A.** (1992). Stratigraphy, structure, and volcanic-hosted mineralization of the Mount Windsor Subprovince, north Queensland, Australia. *Econ. Geol.*, **87**, 739 - 763.

Bertrand, J., Cloete, M., and **Martini, J.E.J.** (1993). Comparison between Archaean komatiitic to tholeiitic lava flows and Mesozoic ophiolitic volcanics: example of the Barberton greenstone belt and the western Alps. *Abstr. Ancient Volcanism and Modern Analogues, IAVCEI, Canberra*, p. 9.

Beukes, N.J. (1973). Precambrian iron-formations of southern Africa. *Econ. Geol.*, **68**, 960 - 1004.

Beutner, E.C., and **Charles, E.G.** (1985). Large volume loss during cleavage formation, Hamburg sequence, Pennsylvania. *Geology*, **13**, 803 - 805.

Bhatia, M.R., and **Crook, K.A.W.** (1986). Trace element characteristics of graywackes and tectonic setting discrimination of sedimentary basins. *Contr. Miner. Petrol.*, **92**, 181 - 193.

Bickle, M.J. (1978). Heat loss from the Earth: a constraint on Archaean tectonics from the relation between geothermal gradients and the rate of plate production. *Earth Planet. Sci. Lett.*, **40**, 301 - 315.

Bickle, M.J. (1986). Implications of melting for stabilisation of the lithosphere and heat loss in the Archaean. *Earth Planet. Sci. Lett.*, **80**, 314 - 324.

Bickle, M.J., Bettenay, L.F., Barley, M.E., Chapman, H.J., Grove D.I., Campbell, I.H., and **De Laeter J.R.** (1983). A 3500 Ma plutonic and volcanic calc-alkaline province in the Archaean East Pilbara Block. *Contr. Miner. Petrol.*, **84**, 25 - 35.

Bickle, M.J., Bettenay, L.F., Chapman, H.J., Groves, D.I., McNaughton, N.J., Campbell, I.H., and **De Laeter, J.R.** (1993). Origin of the 3500 - 3300 Ma calc-alkaline rocks of the Pilbara Archaean: isotopic and geochemical constraints from the Shaw batholith. *Precambrian Res.*, **60**, 117 - 149.

Blum, N., and **Crocket, J.H.** (1992). Repetitive cyclical volcanism in the late Archean Larder Lake Group near Kirkland Lake, Ontario: implications of geochemistry on magma genesis. *Precambrian Res.*, **54**, 173 - 1

Bouma, A.H. (1962). *Sedimentology of Some Flysch Deposits - a Graphic Approach to Facies Interpretation*. Elsevier, Amsterdam, 168 pp.

Bowers, T.S., Jackson, K.J., and **Helgeson, H.C.** (1984). *Equilibrium Activity Diagrams for Coexisting Minerals and Aqueous Solutions at Pressures and Temperatures to 5 kb and 600°C*. Springer-Verlag, Berlin, 397 pp.

Brévart, O., Dupré, B., and **Allégre, C.J.** (1986). Lead-lead age of komatiitic lavas and limitations on the structure and evolution of the Precambrian mantle. *Earth Planet. Sci. Lett.*, **77**, 293 - 302.

Briggs, R.M., and **McDonough, W.F.** (1990). Contemporaneous convergent margin and intraplate magmatism, North Island, New Zealand. *J. Petrol.*, **31**, 813 - 851.

Briqueu, L., Bougault, H., and **Joron, J.L.** (1984). Quantification of Nb, Ta, Ti and V anomalies in magmas associated with subduction zones: petrogenetic implications. *Earth Planet. Sci. Lett.*, **68**, 297 - 308.

Brown, G.C., Thorpe, R.S., and **Webb, P.C.** (1984). The geochemical characteristics of granitoids in contrasting arcs and comments on magma sources. *J. geol. Soc. Lond.*, **141**, 413 - 426.

Brun, J.P., and **Pons, J.** (1981). Strain patterns of pluton emplacement in a crust undergoing non-coaxial deformation, Sierra Morena, southern Spain. *J. Struct. Geol.*, **3**, 219 - 229.

Burrows, D.R, Wood, P.C., and **Spooner, E.T.C.** (1986). Carbon isotope evidence for a magmatic origin for Archaean gold-quartz vein ore deposits. *Nature*, **321**, 851 - 854.

Byerly, G.R., and **Palmer, M.R.** (1991). Tourmaline mineralization in the Barberton greenstone belt, South Africa: early Archean metasomatism by evaporite-derived boron. *Contr. Miner. Petrol.*, **107**, 387 - 402.

Cameron, E.M. (1988). Archean gold: relation to granulite formation and redox zoning in the crust. *Geology*, **16**, 109 - 112.

Campbell, I.H., Coad, P., Franklin, J.M., Gorton, M.P., Scott, S.D., Sowa, J., and **Thurston, P.C.** (1982). Rare earth elements in volcanic rocks associated with Cu-Zn massive sulphide mineralization: a preliminary report. *Can. J. Earth Sci.*, **19**, 619 - 623.

Campbell, I.H., Lesher, C.M., Coad, P., Franklin, J.M., Gorton, M.P., and **Thurston, P.C.** (1984). Rare-earth element mobility in alteration pipes below massive Cu-Zn-sulfide deposits. *Chem. Geol.*, **45**, 181 - 202.

Car, D., and **Ayres, L.D.** (1991). A thick dacitic debris flow sequence, Lake of the Woods greenstone terrane, central Canada: resedimented products of Archean vulcanian, plinian and dome-building eruptions. *Precambrian Res.*, **50**, 239 - 260.

Cas, R.A.F. (1992). Submarine volcanism: eruption styles, products, and relevance to understanding the host-rock successions to volcanic-hosted massive sulfide deposits. *Econ. Geol.*, **87**, 511 - 541.

Cas, R.A.F., and **Wright, J.V.** (1987). *Volcanic Successions - Modern and Ancient. A Geological Approach to Processes, Products and Successions.* Allen and Unwin, London, 528 pp.

Cassidy, K.F., Barley, M.E., Groves, D.I., Perring, C.S., and **Hallberg, J.A.** (1991). An overview of the nature, distribution and inferred tectonic setting of granitoids in the late-Archaean Norseman-Wiluna belt. *Precambrian Res.*, **51**, 51 - 83.

Cathles, L.M., Guber, A.L., Lenagh, T.C., and **Dudás, F.O.** (1983). Kuroko-type massive sulfide deposits of Japan: products of an aborted island-arc rift. *Econ. Geol. Mon.*, **5**, 96 - 114.

Chatterjee, N.D., and **Johannes, W.** (1974). Thermal stability and standard thermodynamic properties of synthetic $2M_1$-muscovite, $KAl_2[AlSi_3O_{10}(OH)_2]$. *Contr. Miner. Petrol.*, **48**, 89 - 114.

Cloete, M. (1990). The metamorphic history of the Komati Formation (Barberton, South Africa): a P-T-t path and its tectonic implications. *Ext. Abstr. 3rd Int. Archaean Symposium, Perth*, 121 - 123.

Cloete, M. (1991). An overview of metamorphism in the Barberton greenstone belt, 84 - 98. *In:* Ashwal, L.D., Ed., *Two Cratons and an Orogen - Excursion Guidebook and Review Articles for a Field Workshop Through Selected Archaean Terranes of Swaziland, South Africa and Zimbabwe.* IGCP Project **280**, Dept. Geol., Univ. Witwatersrand, Johannesburg, 312 pp.

Cloete, M. (1994). *Aspects of volcanism and metamorphism of the Onverwacht Group lavas in the south-western portion of the Barberton greenstone belt.* Ph.D. thesis (unpubl.), Univ. Witwatersrand, Johannesburg, 419 pp.

Cole, J.W. (1981). Genesis of lavas of the Taupo Volcanic Zone, North Island, New Zealand. *J. Volcanol. Geotherm. Res.*, **10**, 317 - 337.

Collins, W.J. (1993). Melting of Archaean sialic crust under high aH_2O conditions: genesis of 3300 Ma Na-rich granitoids in the Mount Edgar batholith, Pilbara Block, Western Australia. *Precambrian Res.*, **60**, 151 - 179.

Compston, W., and **Kröner, A.** (1988). Multiple zircon growth within early Archaean tonalitic gneiss from the Ancient Gneiss Complex, Swaziland. *Earth Planet. Sci. Lett.*, **87**, 13 - 28.

Condie, K.C. (1986). Geochemistry and tectonic setting of early Proterozoic supracrustal rocks in the southwestern United States. *J. Geol.*, **94**, 845 - 864.

Condie, K.C. (1989). Geochemical changes in basalts and andesites across the Archean-Proterozoic boundary: identification and significance. *Lithos*, **23**, 1 - 18.

Condie, K.C., and **Harrison, N.M.** (1976). Geochemistry of the Archean Bulawayan Group, Midlands greenstone belt, Rhodesia. *Precambrian Res.*, **3**, 253 - 271.

Condie, K.C., Macke, J.E., and **Reimer, T.O.** (1970). Petrology and geochemistry of early Precambrian graywackes from the Fig Tree Group, South Africa. *Bull. geol. Soc. Amer.*, **81**, 2759 - 2776.

Courrioux, G. (1987). Oblique diapirism: the Criffel granodiorite / granite zoned pluton (southwest Scotland). *J. Struct. Geol.*, **9**, 313 - 330.

Coward, M.P. (1981). Diapirism and gravity tectonics: report of a Tectonic Studies Group conference held at Leeds University, 25 - 26 March 1980. *J. Struct. Geol.*, **3**, 89 - 95.

Cullers, R.L., DiMarco, M.J., Lowe, D.R., and **Stone, J.** (1993). Geochemistry of a silicified, felsic volcaniclastic suite from the early Archaean Panorama Formation, Pilbara Block, Western Australia: an evaluation of depositional and post-depositional processes with special emphasis on the rare-earth elements. *Precambrian Res.*, **60**, 99 - 116.

Danchin, R.V. (1967). Chromium and nickel in the Fig Tree shale from South Africa. *Science*, **158**, 261 - 262.

Daneel, G.J. (1986). *The structural controls of gold mineralization in the Moodies Hills which surround the Agnes Gold Mine, Barberton greenstone belt.* M.Sc. thesis (unpubl.), Univ. Natal, Durban, 129 pp.

Darracott, B.W. (1975). The interpretation of the gravity anomaly over the Barberton Mountain Land, South Africa. *Trans. geol. Soc. S. Afr.*, **78**, 123 - 128.

Davies, G.F. (1992). On the emergence of plate tectonics. *Geology*, **20**, 963 - 966.

De Beer, J.H., Stettler, E.H., Du Plessis, J.G., and **Blume, J.** (1988). The deep structure of the Barberton greenstone belt: a geophysical study. *Trans. geol. Soc. S. Afr.*, **91**, 184 - 197.

Defant, M.J., and **Drummond, M.S.** (1990). Derivation of some modern arc magmas by melting of young subducted lithosphere. *Nature*, **347**, 662 - 665.

De La Roche, H., Leterrier, J., Grandclaude, P., and **Marchal, M.** (1980). A classification of volcanic and plutonic rocks using R_1R_2-diagram and major-element analyses - its relationships with current nomenclature. *Chem. Geol.*, **29**, 183 - 210.

De Ronde, C.E.J., and **De Wit, M.J.** (in press). The tectonic history of the Barberton greenstone belt, South Africa: ~450 million years of Archean crustal evolution. *Tectonics*.

De Ronde, C.E.J., Kamo, S., Davis, D.W., De Wit, M.J., and **Spooner, E.T.C.** (1991a). Field, geochemical and U-Pb isotopic constraints from hypabyssal felsic intrusions within the Barberton greenstone belt, South Africa: implications for tectonics and timing of gold mineralization. *Precambrian Res.*, **49**, 261 - 280.

De Ronde, C.E.J., De Wit, M.J., Spooner, E.T.C., and **Bray, C.J.** (1991b). Mafic-ultramafic hosted, shear zone related, Au-quartz vein deposits in the Barberton greenstone belt, South Africa: structural style, fluid properties and light stable isotope geochemistry. *Ext. Abstr. Brazil Gold '91, Belo Horizonte, Brazil*, 279 - 286.

De Ronde, C.E.J., Spooner, E.T.C., De Wit, M.J., and Bray, C.J. (1992). Shear zone-related, Au quartz vein deposits in the Barberton greenstone belt, South Africa: field and petrographic characteristics, fluid properties, and light stable isotope geochemistry. *Econ. Geol.*, **87**, 366 - 402.

De Ronde, C.E.J., De Wit, M.J., and Spooner, E.T.C. (1994). Early Archean (>3.2 Ga) Fe-oxide-rich, hydrothermal discharge vents in the Barberton greenstone belt, South Africa. *Bull. geol. Soc. Amer.*, **106**, 86 - 104.

De Rosen-Spence, A.F., Provost, G., Dimroth, E., Gochnauer, K., and Owen, V. (1980). Archean subaqueous felsic flows, Rouyn-Noranda, Quebec, Canada, and their Quaternary equivalents. *Precambrian Res.*, **12**, 43 - 77.

De Villiers, J.E. (1957). The mineralogy of the Barberton gold deposits. *Bull. geol. Surv. S. Afr.*, **24**, 60 pp.

Dewey, J.F., and Windley, B.F. (1981). Growth and differentiation of continental crust. *Phil. Trans. Roy. Soc. Lond.*, **A301**, 189 - 206.

De Wit, M.J. (1982). Gliding and overthrust nappe tectonics in the Barberton greenstone belt. *J. Struct. Geol.*, **4**, 117 - 136.

De Wit, M.J. (1983). Notes on a preliminary 1:25 000 geological map of the southern part of the Barberton greenstone belt. *Spec. Publ. geol. Soc. S. Afr.*, **9**, 185 - 187.

De Wit, M.J. (1991). Archaean greenstone belt tectonism and basin development: some insights from the Barberton and Pietersburg greenstone belts, Kaapvaal Craton, South Africa. *J. Afr. Earth Sci.*, **13**, 45 - 63.

De Wit, M.J., and Hart, R.J. (1993). Earth's earliest continental lithosphere, hydrothermal flux and crustal recycling. *Lithos*, **30**, 309 - 335.

De Wit, M.J., and Tredoux, M. (1988). PGE in the 3.5 Ga Jamestown Ophiolite Complex, Barberton greenstone belt, with implications for PGE distribution in simatic lithosphere, 319 - 342. *In:* Prichard, H.M., Potts, R.J., Bowles, J.F.W., and Cribb, S.J., Eds., *Geoplatinum '87*. Elsevier Applied Science, London, 420 pp.

De Wit, M.J., Hart, R., Martin, A., and Abbott, P. (1982). Archean abiogenic and probable biogenic structures associated with mineralized hydrothermal vent systems and regional metasomatism, with implications for greenstone belt studies. *Econ. Geol.*, **77**, 1783 - 1802.

De Wit, M.J., Fripp, R.E.P., and Stanistreet, I.G. (1983). Tectonic and stratigraphic implications of new field observations along the southern part of the Barberton greenstone belt. *Spec. Publ. geol. Soc. S. Afr.*, **9**, 21 - 292.

De Wit, M.J., Armstrong, R., Hart, R.J., and **Wilson, A.H.** (1987a). Felsic igneous rocks within the 3.3- to 3.5 Ga Barberton greenstone belt: high crustal level equivalents of the surrounding tonalite-trondhjemite terrain, emplaced during thrusting. *Tectonics*, **6**, 529 - 549.

De Wit, M.J., Hart, R.A., and **Hart, R.J.** (1987b). The Jamestown Ophiolite Complex, Barberton mountain belt: a section through 3 5 Ga oceanic crust. *J. Afr. Earth Sci.*, **6**, 681 - 730.

De Wit, M.J., Roering, C., Hart, R.J., Armstrong, R.A., De Ronde, C.E.J., Green, R.W.E., Tredoux, M., Peberdy, E., and **Hart, R.A.** (1992). Formation of an Archaean continent. *Nature*, **357**, 553 - 562.

Dolozi, M.D., and **Ayres, L.D.** (1991). Early Proterozoic basaltic andesite tuff-breccia: downslope, subaqueous mass transport of phreatomagmatically-generated tephra. *Bull. Volcanol.*, **53**, 477 - 495.

Dostal, J., Keppie, J.D., and **Zhai, M.** (1992). Geochemistry of mineralized and barren, Late Proterozoic felsic volcanic rocks in southeastern Cape Breton Island, Nova Scotia (Canada). *Precambrian Res.*, **56**, 33 - 49.

Drummond, M.S., and **Defant, M.J.** (1990). A model for trondhjemite - tonalite - dacite genesis and crustal growth via slab melting: Archean to modern comparisons. *J. Geophys. Res.*, **B95**, 21503 - 21521.

Duchač, K.C., and **Hanor, J.S.** (1987). Origin and timing of the metasomatic silicification of an early Archean komatiite sequence, Barberton Mountain Land, South Africa. *Precambrian Res.*, **37**, 125 - 146.

Gariépy, B., and **Arndt, N.T.** (1990). Pb isotopic compositions of Archean komatiites and sulfides. *Chem. Geol.*, **85**, 35 - 56.

Eglington, B.M., and **Harmer, R.E.** (1991). GEODATE: a program for the processing and regression of isotope data using IBM-compatible microcomputers. *CSIR Manual*, **EMA-H 9101**, 57 pp

El Bouseily, A.M., and **El Sokkary, A.A.** (1975). The relation between Rb, Ba and Sr in granitic rocks. *Chem. Geol.*, **16**, 207 - 219.

England, R.W. (1990). The identification of granitic diapirs. *J. geol. Soc. Lond.*, **147**, 931 - 933.

Erasmus, C.S., Fesq, H.W., Kable, E.J.D., Rasmussen, S.E., and **Sellschop, J.P.F.** (1977). The NIMROC samples as reference materials for neutron activation analysis. *J. Radioanal. Chem.*, **39**, 323 - 334.

Eriksson, K.A. (1977). Tidal deposits from the Archaean Moodies Group, Barberton Mountain Land, South Africa. *Sedim. Geol.*, **18**, 257 - 281.

Eriksson, K.A. (1979). Marginal marine depositional processes from the Archaean Moodies Group, Barberton Mountain Land, South Africa: evidence and significance. *Precambrian Res.*, **8**, 153 - 182.

Eriksson, K.A. (1980a). Hydrodynamic and paleogeographic interpretation of turbidite deposits from the Archean Fig Tree Group of the Barberton Mountain Land, South Africa. *Bull. geol. Soc. Amer.*, **91**, 21 - 26.

Eriksson, K.A. (1980b). Transitional sedimentation styles in the Moodies and Fig Tree Groups, Barberton Mountain Land, South Africa: evidence favouring an Archean continental margin. *Precambrian Res.*, **12**, 141 - 160.

Evensen, N.M., Hamilton, P.J., and **O'Nions, R.K.** (1978). Rare earth abundances in chondritic meteorites. *Geochim. cosmochim. Acta*, **42**, 1199 - 1212.

Ewart, A. (1979). A review of the mineralogy and chemistry of Tertiary - Recent dacitic, latitic, rhyolitic, and related salic volcanic rocks, 13 - 121. *In:* Barker, F., Ed., *Trondhjemites, Dacites and Related Rocks*. Elsevier, Amsterdam, 659 pp.

Ewart, A. (1982). The mineralogy and petrology of Tertiary - Recent orogenic rocks: with special reference to the andesitic - basaltic compositional range, 25 - 95. *In:* Thorpe, R.S., Ed., *Andesites: Orogenic Andesites and Related Rocks*. John Wiley and Sons, Chichester, 724.

Feng, R., and **Kerrich, R.** (1992). Geochemical evolution of granitoids from the Archean Abitibi Southern Volcanic Zone and Pontiac subprovince, Superior Province, Canada: implications for tectonic history and source regions. *Chem. Geol.*, **98**, 23 - 70.

Fesq, H.W., Bibby, D.M., Sellschop, J.P.F., and **Watterson, J.I.W.** (1973). The determination of trace element impurities in natural diamonds by instrumental neutron activation analysis. *J. Radioanal. Chem.*, **17**, 195 - 216.

Finlow-Bates, T., and **Stumpfl, E.F.** (1981). The behaviour of so-called immobile elements in hydrothermally altered rocks associated with volcanogenic submarine-exhalative ore deposits. *Mineral. Deposita*, **16**, 319 - 328.

Fisher, R.V., and **Schmincke, H.U.** (1984). *Pyroclastic Rocks*. Springer Verlag, Berlin, 472 pp.

Flinn, D. (1962). On folding during three-dimensional progressive deformation. *Q. J. geol. Soc. Lond.*, **118**, 385 - 433.

Foley, S.F., and **Wheller, G.E.** (1990). Parallels in the origin of the geochemical signatures of island arc volcanics and continental potassic igneous rocks: the role of residual titanites. *Chem. Geol.*, **85**, 1 - 18.

Fourcade, S., and **Allégre, C.J.** (1981). Trace elements behaviour in granite genesis: a case study. The calc-alkaline plutonic association from the Querigut Complex (Pyrénées, France). *Contr. Miner. Petrol.*, **76**, 177 - 195.

Franklin, J.M. (1986). Volcanic-associated massive sulphide deposits - an update, 49 - 82. *In:* Andrew, C.J., Crowe, R.W.A., Finlay, S., Pennell, W.M., and Pyne, J.F., Eds., *Geology and Genesis of Mineral Deposits in Ireland*. Irish Assoc. Econ. Geol., Dublin, 709 pp.

Frater, K.M. (1983). Effects of metasomatism and development of quartz 'eyes' in intrusive and extrusive rocks at Golden Grove Cu-Zn deposit, Western Australia. *Trans. Instn. Min. Metall.*, **B92**, 121 - 131.

Frimmel, H.E. (1994). Metamorphism of Witwatersrand gold. *Dept. Geol. Sci. Inform. Circ., Univ. Cape Town*, **13**, 1 - 16.

Fripp, R.E.P., Van Nierop, D.A., Callow, M.J., Lilly, P.A., and **Du Plessis, L.U.** (1980). Deformation in part of the Archaean Kaapvaal Craton, South Africa. *Precambrian Res.*, **13**, 241 - 251.

Ganguly, J. (1969). Chloritoid stability and related parageneses: theory, experiments and applications. *Amer. J. Sci.*, **267**, 910 - 944.

Gay, N.C. (1964). The composition of gold from the Barberton Mountain Land. *Inform. Circ. Econ. Geol. Res. Unit, Univ Witwatersrand, Johannesburg*, **19**, 53 pp.

Gélinas, L., Trudel, P., and **Hubert, C.** (1984). Chemostratigraphic division of the Blake River Group, Rouyn-Noranda area, Abitibi, Quebec. *Can. J. Earth Sci.*, **20**, 220 - 231.

Giles, C.W., and **Hallberg, J.A.** (1982). The genesis of the Archaean Welcome Well volcanic complex, Western Australia. *Contr. Miner. Petrol.*, **80**, 307 - 318.

Glikson, A.Y. (1976). Trace element geochemistry and origin of early Precambrian acid igneous series, Barberton Mountain Land, Transvaal. *Geochim. cosmochim. Acta*, **40**, 1261 - 1280.

Glikson, A.Y., and **Jahn, B.M.** (1985). REE and LIL elements, eastern Kaapvaal Shield, South Africa: evidence of crustal evolution by 3-stage melting, 303 - 324. *In:* Ayres, L.D., Thurston, P.C., Card, K.D., and Weber, W., Eds., *Evolution of Archean Supracrustal Sequences*. Spec. Pap. geol. Assoc. Canada., **28**, 380 pp.

Gorman, B.E., Pearce, T.H., and **Birkett, T.C.** (1978). On the structure of Archean greenstone belts. *Precambrian Res.* **6**, 23 - 41.

Grant, J.A. (1986). The isocon diagram - a simple solution to Gresen's equation for metasomatic alteration. *Econ. Geol.*, **81**, 1976 - 1982.

Groeneveld, D. *(Compiler)* (1973). The economic mineral deposits in the Archaean complex of the Barberton area. *Unpubl. Rep. geol. Surv. S. Afr.*, 353 pp.

Gromet, L.P., and **Silver, L.T.** (1983). Rare earth element distributions among minerals in a granodiorite and their petrogenetic implications. *Geochim. cosmochim. Acta*, **47**, 925 - 939.

Gromet, L.P., Dymek, R.F., Haskin, L.A., and **Korotev, R.L.** (1984). The "North American shale composite": its compilation, major and trace element characteristics. *Geochim. cosmochim. Acta*, **48**, 2469 - 2482.

Groves, D.I., Golding, S.D., Rock, N.M.S., Barley, M.E., and **McNaughton, N.J.** (1988). Archaean carbon reservoirs and their relevance to the fluid source for gold deposits. *Nature*, **331**, 254 - 257.

Gruau, G., Chauvel, C., and **Jahn, B.M.** (1990). Anomalous Sm-Nd ages for the early Archean Onverwacht Group volcanics. Significance and petrogenetic implications. *Contr. Miner. Petrol.*, **104**, 27 - 34.

Guber, A.L., and **Merrill, S.** (1983). Paleobathymetric significance of the formaminifera from the Hokuroku District. *Econ. Geol. Mon.*, **5**, 55 - 70.

Halbach, P., and 17 others (1989). Probable modern analogue of Kuroko-type massive sulphide deposits in the Okinawa Trough back-arc basin. *Nature*, **338**, 496 - 499.

Hall, A.L. (1918). The geology of the Barberton gold mining district. *Mem. geol. Surv. S. Afr.*, **9**, 347 pp.

Hamilton, P.J., Evensen, N.M., O'Nions, R.K., Smith, H.S., and **Erlank, A.J.** (1979). Sm-Nd dating of Onverwacht Group volcanics, southern Africa. *Nature*, **279**, 298 - 300.

Hamilton, P.J., O'Nions, R.K., Bridgwater, D., and **Nutman, A.** (1983). Sm-Nd studies of Archaean metasediments and metavolcanics from West Greenland and their implications for the Earth's early history. *Earth Planet. Sci. Lett.*, **62**, 263 - 272.

Hamilton, W.B. (1988). Plate tectonics and island arcs. *Bull. geol. Soc. Amer.*, **100**, 1503 - 1527.

Hanor, J.S., and **Duchač, K.** (1990). Isovolumetric silicification of early Archean komatiites: geochemical mass balances and constraints on origin. *J. Geol.*, **98**, 863 - 877.

Hanson, G.N. (1978). The application of trace elements to the petrogenesis of igneous rocks of granitic composition. *Earth Planet. Sci. Lett.*, **38**, 26 - 43.

Hargraves, R.B. (1986). Faster spreading or greater ridge length in the Archean. *Geology*, **14**, 750 - 752.

Harpum, J.R. (1963). Petrographic classification of granitic rocks in Tanganyika by partial chemical analyses. *Rec. geol. Surv. Tanganyika*, **10**, 80 - 88.

Harris, N.B.W., and **Inger, S.** (1992). Trace element modelling of pelite-derived granites. *Contr. Miner. Petrol.*, **110**, 46 - 56.

Harris, N.B.W., Pearce, J.A., and **Tindle, A.G.** (1986). Geochemical characteristics of collision-zone magmatism, 67 - 81. *In:* Coward, M.P., and Ries, A.C., Eds., *Collision Tectonics*. Spec. Publ. geol. Soc., **19**, 415 pp.

Harris, P.D., Robb, L.J., and **Tomkinson, M.J.** (1993). The nature and structural setting of rare-element pegmatites along the northern flank of the Barberton greenstone belt, South Africa. *Inform. Circ. Econ. Geol. Res. Unit, Univ. Witwatersrand, Johannesburg*, **261**, 28 pp.

Harte, B., and **Graham, C.M.** (1975). The graphical analysis of greenschist to amphibolite facies mineral assemblages in metabasites. *J. Petrol.*, **16**, 347 - 370.

Harwood, A., and **Murphy, P.W.** (1988). The petrology of the Bien Venue polymetallic massive sulphide deposit, Eastern Transvaal. *Ext. Abstr. Geocongress '88, Univ. Natal, Durban*, 811 - 812.

Heinrichs, T.K., and **Reimer, T.O.** (1977). A sedimentary barite deposit from the Archean Fig Tree Group of the Barberton Mountain Land (South Africa). *Econ. Geol.*, **72**, 1426 - 1441.

Helmstaedt, H., Padgham, W.A., and **Brophy, J.A.** (1986). Multiple dikes in Lower Kam Group, Yellowknife geenstone belt: evidence for Archean sea-floor spreading? *Geology*, **14**, 562 - 566.

Hemley, J.J. (1959). Some mineralogical equilibria in the system K_2O-Al_2O_3-SiO_2-H_2O. *Amer. J. Sci.*, **257**, 241 - 270.

Hemley, J.J., and **Hunt, J.P.** (1992). Hydrothermal ore-forming processes in the light of studies in rock-buffered systems: II. Some general geologic applications. *Econ. Geol.*, **87**, 23 - 43.

Hemley, J.J., Montoya, J.W., Marinenko, J.W., and **Luce, R.W.** (1980). Equilibria in the system Al_2O_3-SiO_2-H_2O and some general implications for alteration / mineralization processes. *Econ. Geol.* **75**, 210 - 228.

Heubeck, C. (1990). A structural transect across the central part of the early Archaean Barberton greenstone belt, southern Africa. *Ext. Abstr. 3rd Int. Archaean Symposium, Perth*, 111 - 112.

Heubeck, C., and Lowe, D.R. (1993). Syndeformational deposition, northern provenance, and foreland basin setting of the Moodies Group in the central Barberton greenstone belt, South Africa. *Ext. Abstr. 16th Int. Coll. Afr. Geol., Mbabane*, 153 - 154.

Heubeck, C., and Lowe, D.R. (1994). Depositional and tectonic setting of the Archean Moodies Group, Barberton greenstone belt, South Africa. *Precambrian Res.*, **68**, 257 - 290.

Heubeck, C., Wendt, J.I., Toulkeridis, T., Kröner, A., and Lowe, D.R. (1993). Timing of deformation of the early Archaean Barberton greenstone belt, South Africa: constraints from zircon dating of the Salisbury Kop pluton. *Trans. geol. Soc. S. Afr.*, **96**, 1 - 8.

Hildreth, W., and Moorbath, S. (1988). Crustal contributions to arc magmatism in the Andes of Central Chile. *Contr. Miner. Petrol.*, **98**, 455 - 489.

Hollywood, T.P. (1976). "Quartz-eye"-bearing porphyroidal rocks and volcanogenic massive sulfide deposits. *Econ. Geol.*, **71**, 589 - 612.

Houstoun, S.M. (1987). Competency contrasts and chemical controls as guides to gold mineralization: an example from the Barberton Mountain Land, 147 - 160. *In:* Ho, S.E., and Groves, D.I., Eds., *Recent Advances in Understanding Precambrian Gold Deposits*. Geol. Dept. and Univ. Extension, Univ. Western Australia, Publ. **11**, 368 pp.

Hunter, D.R. (1970). The Ancient Gneiss Complex in Swaziland. *Trans. geol. Soc. S. Afr.*, **73**, 107 - 150.

Hunter, D.R. (1973). The granitic rocks of the Precambrian in Swaziland. *Spec. Publ. geol. Soc. S. Afr.*, **3**, 131 - 145.

Hunter, D.R. (1974). Crustal development in the Kaapvaal Craton, I. The Archaean. *Precambrian Res.*, **1**, 259 - 294.

Hunter, D.R. (1991). Crustal processes during Archaean evolution of the southeastern Kaapvaal Province. *J. Afr. Earth Sci.*, **13**, 13 - 25.

Hunter, D.R., and Reid, D.L. (1987). Mafic dyke swarms in southern Africa, 445 - 456. *In:* Halls, H.C., and Fahrig, W.F., Eds., *Mafic Dyke Swarms*. Spec. Pap. geol. Assoc. Can., **34**, 503 pp.

Hutchinson, R.W. (1980). Massive base metal sulphide deposits as guides to tectonic evolution, 659 - 684. *In:* Strangway, D.W., Ed., *The Continental Crust and its Mineral Deposits*. Spec. Pap. geol. Assoc. Can., **20**, 804 pp.

Hutchinson, R.W. (1990). Precious metals in massive base metal sulfide deposits. *Geol. Rundsch.*, **79**, 241 - 263.

Irvine, T.N., and **Barager, W.R.A.** (1971). A guide to the chemical classification of the common volcanic rocks. *Can. J. Earth Sci.*, **8**, 523 - 548.

Jackson, M.P.A., and **Robertson, D.I.** (1983). Regional implications of early-Precambrian strains in the Onverwacht Group adjacent to the Lochiel Granite, north-west Swaziland. *Spec. Publ. geol. Soc. S. Afr.*, **9**, 45 - 62.

Jackson, M.P.A., Eriksson, K.A., and **Harris, C.W.** (1987). Early Archean foredeep sedimentation related to crustal shortening: a reinterpretation of the Barberton Sequence, southern Africa. *Tectonophysics*, **136**, 197 - 221.

Jackson, S.L., Fyon, J.A., and **Corfu, F.** (1994). Review of Archean supracrustal assemblages of the southern Abitibi greenstone belt in Ontario, Canada: products of microplate interaction within a large-scale plate-tectonic setting. *Precambrian Res.*, **65**, 183 - 205.

Jahn, B.M., Gruau, G., and **Glikson, A.Y.** (1982). Komatiites of the Onverwacht Group, S. Africa: REE geochemistry, Sm/Nd age and mantle evolution. *Contr. Miner. Petrol.*, **80**, 25 - 40.

Jakeš, P., and **Gill, J.** (1970). Rare earth elements and island arc tholeiitic series. *Earth Planet. Sci. Lett.*, **9**, 17 - 28.

Jasiński, J.W. (1988). Activity diagrams for the MgO-Na_2O-K_2O-SiO_2-Al_2O_3-H_2O-HCl system in the temperature range 298 to 623 K and 1 bar pressure: application to the 1900 Ma phlogopite-Mg-chlorite-sericite schists of W. Bergslagen, Sweden. *Geol. Mijn.*, **67**, 379 - 395.

Jelsma, H.A., Van der Beek, P.A., and **Vinyu, M.L.** (1993). Tectonic evolution of the Bindura - Shamva greenstone belt (northern Zimbabwe): progressive deformation around diapiric batholiths. *J. Struct. Geol.*, **15**, 163 - 176.

Jensen, L.S. (1976). A new cation plot for classifying subalkali volcanic rocks. *Misc. Pap. Ontario Div. Mines*, **66**, 22 pp.

Kamo, S.L., and **Davis, D.W.** (1994). Reassessment of Archean crustal development in the Barberton Mountain Land, South Africa, based on U-Pb dating. *Tectonics*, **13**, 167 - 192.

Kimura, M., Uyeda, S., Kato, Y., Tanaka, T., Yamano, M., Gamo, T., Sakai, H., Kato, S., Izawa, E., and Oomori, T. (1988). Active hydrothermal mounds in the Okinawa Trough backarc basin, Japan. *Tectonophysics*, **145**, 319 - 324.

Kisters, A.F.M., and Anhaeusser, C.R. (1993). Fabric development and deformation of greenstone xenoliths in Archaean TTG plutons and regional implications for the tectonic evolution of the Barberton greenstone belt, South Africa. *Inform. Circ. Econ. Geol. Res. Unit, Univ. Witwatersrand, Johannesburg*, **273**, 28 pp.

Kohler, E.A., Anhaeusser, C.R., and Meyer, F.M. (1992). The geology of the granite-greenstone terrane in the Louw's Creek area, Barberton greenstone belt. *Ext. Abstr. Geocongress '92, Univ. Orange Free State, Bloemfontein*, 242 - 244.

Kohler, E.A., Anhaeusser, C.R., and Isachsen, C. (1993). The Bien Venue Formation: a proposed new unit in the northeastern sector of the Barberton greenstone belt. *Ext. Abstr. 16th Int. Coll. Afr. Geol., Mbabane*, 186 - 187.

Kröner, A. (1985). Evolution of the Archean continental crust. *Ann. Rev. Earth Planet. Sci.*, **13**, 49 - 74.

Kröner, A. (1993). Contemporaneous evolution of an early Archaean gneiss-granitoid-greenstone terrain as exemplified by the Ancient Gneiss Complex and the Barberton greenstone belt, Swaziland and South Africa. *Ext. Abstr. 16th Int. Coll. Afr. Geol., Mbabane*, 195 - 197.

Kröner, A., and Compston, W. (1988). Ion microprobe ages of zircons from early Archaean granite pebbles and greywacke, Barberton greenstone belt, southern Africa. *Precambrian Res.*, **38**, 367 - 380.

Kröner, A., and Layer, P.W. (1992). Crust formation and plate motion in the early Archaean. *Science*, **256**, 1405 - 1411.

Kröner, A., and Todt, W. (1988). Single zircon dating constraining the maximum age of the Barberton greenstone belt, southern Africa. *J. Geophys. Res.*, **93**, 15329 - 15337.

Kröner, A., Compston, W., and Williams, I.S. (1989). Growth of early Archaean crust in the Ancient Gneiss Complex of Swaziland as revealed by single zircon dating. *Tectonophysics*, **161**, 271 - 298.

Kröner, A., Byerly, G.R., and Lowe, D.R. (1991a). Chronology of early Archaean granite-greenstone evolution in the Barberton Mountain Land, South Africa, based on precise dating by single zircon evaporation. *Earth Planet. Sci. Lett.*, **103**, 41 - 54.

Kröner, A., Wendt, J.I., Tegtmeyer, A.R., Milisenda, C., and **Compston, W.** (1991b). Geochronology of the Ancient gneiss Complex, Swaziland, and implications for crustal evolution, 8 - 31. *In:* Ashwal, L.D., Ed., *Two Cratons and an Orogen - Excursion Guidebook and Review Articles for a Field Workshop Through Selected Archaean Terranes of Swaziland, South Africa and Zimbabwe*. IGCP Project **280**, Dept. Geol., Univ. Witwatersrand, Johannesburg, 312 pp

Laird, J. (1980). Phase equilibria in mafic schist from Vermont. *J. Petrol.*, **21**, 1 - 37.

Laird, J., and **Albee, A.L.** (1981). Pressure, temperature and time indicators in mafic schist: their application to reconstructing the polymetamorphic history of Vermont. *Amer. J. Sci.*, **281**, 127 - 175.

Lamb, S.H. (1984). Structures on the eastern margin of the Archaean Barberton greenstone belt, northwest Swaziland, 19 - 39. *In:* Kröner, A., and Greiling, R., Eds., *Precambrian Tectonics Illustrated*. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 419 pp.

Lamb, S. (1987). Archean synsedimentary tectonic deformation - a comparison with the Quaternary. *Geology*, **15**, 565 - 568.

Lamb, S., and **Paris, I.** (1988). Post-Onverwacht Group stratigraphy in the SE part of the Archaean Barberton greenstone belt. *J. Afr. Earth Sci.*, **7**, 285 - 306.

Lanier, W.P., and **Lowe, D.R.** (1982). Sedimentology of the Middle Marker (3.4 Ga), Onverwacht Group, Transvaal, South Africa. *Precambrian Res.*, **18**, 237 - 260.

Layer, P.W. (1991). An overview of palaeomagnetism of the Barberton and Swaziland regions, 99 - 108. *In:* Ashwal, L.D., Ed., *Two Cratons and an Orogen - Excursion Guidebook and Review Articles for a Field Workshop Through Selected Archaean Terranes of Swaziland, South Africa and Zimbabwe*. IGCP Project **280**, Dept. Geol., Univ. Witwatersrand, Johannesburg, 312 pp.

Layer, P.W., Kröner, A., McWilliams, M., and **York, D.** (1989). Elements of the Archean thermal history and apparent polar wander of the eastern Kaapvaal Craton, Swaziland, from single grain dating and paleomagnetism. *Earth Planet. Sci. Lett.*, **93**, 23 - 34.

Le Bas, M.J., Le Maitre, R.W., Streckeisen, A., and **Zanettin, B.** (1986). A chemical classification of volcanic rocks based on the total alkali - silica diagram. *J. Petrol.*, **27**, 745 - 750.

Le Maitre, R.W. (1976). The chemical variability of some common igneous rocks. *J. Petrol.*, **17**, 589 - 637.

Lesher, C.M., and **Campbell, I.H.** (1987). Trace-element geochemistry of ore-associated and barren, felsic metavolcanic rocks in the Superior Province, Canada: reply. *Can. J. Earth Sci.*, **24**, 1500 - 1501.

Lesher, C.M., Goodwin, A.M., Campbell, I.H., and **Gorton, M.P.** (1986). Trace-element geochemistry of ore-associated and barren, felsic metavolcanic rocks in the Superior Province, Canada. *Can. J. Earth Sci.*, **23**, 222 - 237.

Liebenberg, W.R. (1972). Mineralogical features of gold ores in South Africa, 352 - 452. *In:* Adamson, R.J., Ed., *Gold Metallurgy in South Africa*. Chamber of Mines of South Africa, 452 pp.

López-Martinez, M., York, D., and **Hanes, J.A.** (1992). A $^{40}Ar/^{39}Ar$ geochronological study of komatiites and komatiitic basalts from the lower Onverwacht volcanics: Barberton Mountain Land, South Africa. *Precambrian Res.*, **57**, 91 - 119.

Lowe, D.R. (1980). Archean sedimentation. *Ann. Rev. Earth Planet. Sci.*, **8**, 145 - 167.

Lowe, D.R. (1982). Comparative sedimentology of the principal volcanic sequences of Archean greenstone belts in South Africa, Western Australia and Canada: implications for crustal evolution. *Precambrian Res.*, **17**, 1 - 29.

Lowe, D.R. (1985). Sedimentary environment as a control on the formation and preservation of Archean volcanogenic massive sulphide deposits, 193 - 201. *In:* Ayres, L.D., Thurston, P.C., Card, K.D., and Weber, W., Eds., *Evolution of Archean Supracrustal Sequences*. Spec. Pap. geol. Assoc. Canada., **28**, 380 pp.

Lowe, D.R. (1991). Geology of the Barberton greenstone belt: an overview, 47 - 58. *In:* Ashwal, L.D., Ed., *Two Cratons and an Orogen - Excursion Guidebook and Review Articles for a Field Workshop Through Selected Archaean Terranes of Swaziland, South Africa and Zimbabwe*. IGCP Project **280**, Dept. Geol., Univ. Witwatersrand, Johannesburg, 312 pp.

Lowe, D.R., and **Byerly, G.R.** (1986). Archaean flow-top alteration zones formed initially in a low-temperature sulphate-rich environment. *Nature*, **324**, 245 - 248.

Lowe, D.R., and **Knauth, L.P.** (1977). Sedimentology of the Onverwacht Group (3.4 billion years), Transvaal, South Africa, and its bearing on the characteristics and evolution of the early Earth. *J. Geol.*, **85**, 699 - 723.

Lowe, D.R., Byerly, G.R., Ransom, B.L., and **Nocita, B.W.** (1985). Stratigraphic and sedimentological evidence bearing on structural repetition in early Archaean rocks of the Barberton greenstone belt, South Africa. *Precambrian Res.*, **27**, 165 - 186.

Ludden, J., Gélinas, L., and Trudel, P. (1982). Archean metavolcanics from the Rouyn - Noranda district, Abitibi greenstone belt, Quebec. 2. Mobility of trace elements and petrogenetic constraints. *Can. J. Earth Sci.*, **19**, 2276 - 2287.

Ludwig, K.R. (1980). Calculation of uncertainties of U-Pb isotope data. *Earth Planet. Sci. Lett.*, **46**, 212 - 220.

Ludwig, K.R. (1988). PBDAT for MS-DOS. A computer program for IBM-PC compatibles for processing raw Pb-U-Th isotope data. *U.S. geol. Surv. Open-file Rep.*, **88-542**, 36 pp.

Luth, W.C., Jahns, R.H., and Tuttle, F.O. (1964). The granite system at pressures of 4 to 10 kilobars. *J. Geophys. Res.*, **69**, 759 - 773.

MacLean, W.H. (1988). Rare earth element mobility at constant inter-REE ratios in the alteration zone at the Phelps Dodge massive sulphide deposit, Matagami, Quebec. *Mineral. Deposita*, **23**, 231 - 238.

MacLean, W.H. (1990). Mass change calculations in altered rock series. *Mineral. Deposita*, **25**, 44 - 49.

MacLean, W.H., and Hoy, L.D. (1991). Geochemistry of hydrothermally altered rocks at the Horne Mine, Noranda, Quebec. *Econ. Geol.*, **86**, 506 - 528.

MacLean, W.H., and Kranidiotis, P. (1987). Immobile elements as monitors of mass transfer in hydrothermal alteration: Phelps Dodge massive sulfide deposit, Matagami, Quebec. *Econ. Geol.*, **82**, 951 - 962.

Maiden, K.J. (1984). Metamorphic features of the Maranda J copper-zinc deposit, Murchison greenstone belt, Transvaal. *Trans. geol. Soc. S. Afr.*, **87**, 335 - 345.

Maniar, P.D., and Piccoli, P.M. (1989). Tectonic discrimination of granitoids. *Bull. geol. Soc. Amer.*, **101**, 635 - 643.

Maphalala, R.M., and Kröner, A. (1993). Pb-Pb single zircon ages for the younger Archaean granitoids of Swaziland, southern Africa. *Ext. Abstr. 16th Int. Coll. Afr. Geol., Mbabane*, 201 - 206.

Martin, H. (1986). Effect of steeper Archean geothermal gradient on geochemistry of subduction-zone magmas. *Geology*, **14**, 753 - 756.

Martin, H. (1987). Petrogenesis of Archaean trondhjemites, tonalites and granodiorite from eastern Finland: major and trace element geochemistry. *J. Petrol.*, **28**, 921 - 953.

Martin, H. (1993). The mechanisms of petrogenesis of the Archaean continental crust - comparison with modern processes. *Lithos*, **30**, 373 - 388.

McCarthy, T.S., and **Hasty, R.A.** (1976). Trace element distribution patterns and their relationship to the crystallization of granitic melts. *Geochim. cosmochim. Acta*, **40**, 1351 - 1358.

McCarthy, T.S., and **Kable, E.J.D.** (1978). On the behaviour of rare-earth elements during partial melting of granitic rock. *Chem. Geol.*, **22**, 21 - 29.

McCarthy, T.S., and **Robb, L.J.** (1978). On the relationship between cumulus mineralogy and trace and alkali element chemistry in an Archaean granite from the Barberton region, South Africa. *Geochim. cosmochim. Acta*, **42**, 21 - 26.

McDonough, W.F., and **Ireland, T.R.** (1993). Intraplate origin of komatiites inferred from trace elements in glass inclusions. *Nature*, **365**, 432 - 434.

McLennan, S.M., Taylor, S.R., and **Kröner, A.** (1983). Geochemical evolution of Archean shales from South Africa. 1. The Swaziland and Pongola Supergroups. *Precambrian Res.*, **22**, 93 - 124.

McPhie, J., and **Allen, R.L.** (1992). Facies architecture of mineralized submarine volcanic sequences: Cambrian Mount Read volcanics, western Tasmania. *Econ. Geol.*, **87**, 587 - 596.

Mehnert, K.R. (1968). *Migmatites and the Origin of Granitic Rocks*. Elsevier, Amsterdam, 393 pp.

Meschede, M. (1986). A method of discriminating between different types of mid-ocean ridge basalts and continental tholeiites with the Nb-Zr-Y diagram. *Chem. Geol.*, **56**, 207 - 218.

Meyer, F.M. (1983). *Geochemische, mineralogische und geologische Untersuchungen an archaischen Granitoiden und frühproterozoischen Sedimenten aus Südafrika: ein Beitrag zur Geochemie von Gold, Thorium und Uran*. Ph.D. thesis, University of Cologne, Germany, 294 pp.

Meyer, F.M., Tainton, S., and **Saager, R.** (1990). The mineralogy and geochemistry of small-pebble conglomerates from the Promise Formation in the West Rand and Klerksdorp areas. *Trans. geol. Soc. S. Afr.*, **93**, 118 - 134.

Meyer, F.M., Robb, L.J., Reimold, W.U., and **De Bruiyn, H.D.** (1992). S- and A-type granites during late-stage magmatism in the Barberton Mountain Land, southern Africa. *Inform. Circ. Econ. Geol. Res. Unit, Univ. Witwatersrand, Johannesburg*, **257**, 18 pp.

Michel-Lévy, A. (1877). De lémploi du microscope polasisant a lumieré paralléle. *Ann. Mines.*, **12**, 392 - 471.

Middlemost, E.A.K. (1989). Iron oxidation ratios, norms and the classification of volcanic rocks. *Chem. Geol.*, **77**, 19 - 26.

Minnitt, R.C.A., and **Anhaeusser, C.R.** (1992). Gravitational and diapiric structural history of the eastern portion of the Archaean Murchison greenstone belt, South Africa. *J. Afr. Earth Sci.*, **15**, 429 - 440.

Mitropoulos, P., and **Tarney, J.** (1992). Significance of mineral composition variations in the Aegean Island Arc. *J. Volcanol. Geotherm. Res.*, **51**, 283 - 303.

Molnar, P., and **Atwater, T.** (1978). Interarc spreading and Cordilleran tectonics as alternates related to the age of subducted oceanic lithosphere. *Earth Planet. Sci. Lett.*, **41**, 330 - 340.

Montoya, J.W., and **Hemley, J.J.** (1975). Activity relations and stabilities in alkali feldspar and mica alteration reactions. *Econ. Geol.*, **70**, 577 - 594.

Morris, R.C. (1993). Genetic modelling for banded iron-formation of the Hamersley Group, Pilbara Craton, Western Australia. *Precambrian Res.*, **60**, 243 - 286.

Müller, D., Rock, N.M.S., and **Groves, D.I.** (1992). Geochemical discrimination between shoshonitic and potassic volcanic rocks in different tectonic settings: a pilot study. *Contr. Miner. Petrol.*, **46**, 259 - 289.

Murphy, P.W. (1990). *The petrology, geochemistry and classification of the Bien Venue massive sulphide deposit, Barberton Mountain Land.* M.Sc. thesis (unpubl.), Univ. Natal, Durban, 111 pp.

Naney, M.T., and **Swanson, S.E.** (1980). The effect of Fe and Mg on crystallization in granitic systems. *Amer. Miner.*, **65**, 639 - 653.

Neumann, H., Mead, J., and **Vitaliano, C.J.** (1954). Trace element variation during fractional crystallization as calculated from the distribution law. *Geochim. cosmochim. Acta*, **6**, 90 - 99.

Nisbet, E.G. (1987). *The Young Earth. An Introduction to Archaean Geology.* Allen and Unwin, Boston, 402 pp.

Nisbet, E.G., and **Fowler, C.M.R.** (1983). Model for Archean plate tectonics. *Geology*, **11**, 376 - 379.

Nishiyama, T. (1990). CO_2-metasomatism of a metabasite block in a serpentine melange from the Nishisonogi metamorphic rocks, southwest Japan. *Contr. Miner. Petrol.*, **104**, 35 - 46.

Nocita, B.W., and **Lowe, D.R.** (1990). Fan-delta sequence in the Archean Fig Tree Group, Barberton greenstone belt, South Africa. *Precambrian Res.*, **48**, 375 - 393.

Norrish, K., and **Hutton, J.T.** (1969). An accurate X-ray spectrographic method for the analysis of a wide range of geological samples. *Geochim. cosmochim. Acta*, **33**, 431 - 453.

Nutman, A.P., and **Collerson, K.D.** (1991). Very early Archean crustal-accretion complexes preserved in the North Atlantic craton. *Geology*, **19**, 791 - 794.

O'Connor, J.T. (1965). A classification for quartz-rich igneous rocks based on feldspar ratios. *U.S. geol. Surv. Prof. Pap.*, **525-B**, 79 - 84.

Ohmoto, H., and **Skinner, B.J.** *(Eds.)* (1983). The Kuroko and related volcanogenic massive sulfide deposits. *Econ. Geol. Mon.*, **5**, 604 pp.

Ohmoto, H., and **Takahashi, T.** (1983). Geological setting of the Kuroko deposits, Japan: Part III. Submarine calderas and Kuroko genesis. *Econ. Geol. Mon.*, **5**, 39 - 54.

Osterberg, S.A., Morton, R.L., and **Franklin, J.M.** (1987). Hydrothermal alteration and physical volcanology of Archean rocks in the vicinity of the Headway-Coulee massive sulfide occurrence, Onaman area, northwestern Ontario. *Econ. Geol.*, **82**, 1505 - 1520.

Padgham, W.A. (1992). Mineral deposits in the Archean Slave Structural Province; lithological and tectonic setting. *Precambrian Res.*, **58**, 1 - 24.

Paris, I.A. (1984). *The geology of the farms Josefsdal, Dunbar and part of Diepgezet in the Barberton greenstone belt*. Ph.D. thesis (unpubl.), Univ. Witwatersrand, Johannesburg, 258 pp.

Paris, I.A. (1990). Depositional environment of the Onverwacht sedimentary rocks, Barberton greenstone belt, South Africa. *J. Afr. Earth Sci.*, **10**, 509 - 518.

Paris, I.A., Stanistreet, I.G., and **Hughes, M.J.** (1985). Cherts of the Barberton greenstone belt interpreted as products of submarine exhalative activity. *J. Geol.*, **93**, 111 - 129.

Parrish, R.R. (1987). An improved micro-capsule for zircon dissolution in U-Pb geochronology. *Chem. Geol. (Isotope Geoscience)*, **66**, 99 - 102.

Paterson, S.R. (1988). Cannibal Creek Granite: post-tectonic "ballooning" pluton or pre-tectonic piercement diapir? *J. Geol.*, **96**, 730 - 736.

Paterson, S.R., Vernon, R.H., and **Tobisch, O.T.** (1989). A review of criteria for the identification of magmatic and tectonic foliations in granitoids. *J. Struct. Geol.*, **11**, 349 - 363.

Pattison, D.M.R. (1992). Stability of andalusite and sillimanite and the Al_2SiO_5 triple point: constraints from the Ballachulish aureole, Scotland. *J. Geol.*, **100**, 423 - 446.

Pearce, J.A. (1982). Trace element characteristics of lavas from destructive plate boundaries, 525 - 548. *In:* Thorpe, R.S., Ed., *Andesites: Orogenic Andesites and Related Rocks*. John Wiley and Sons, Chichester, 724 pp.

Pearce, J.A., and Cann, J.R. (1973). Tectonic setting of basic volcanic rocks determined using trace element analyses. *Earth Planet. Sci. Lett.*, **19**, 290 - 300.

Pearce, J.A., and Norry, M.J. (1979). Petrogenetic implications of Ti, Zr, Y, and Nb variations in volcanic rocks. *Contr. Miner. Petrol.*, **69**, 33 - 47.

Pearce, J.A., Harris, N.B.W., and Tindle, A.G. (1984). Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. *J. Petrol.*, **25**, 956 - 983.

Peccerillo, A. (1992). Potassic and ultrapotassic rocks: compositional characteristics, petrogenesis, and geologic significance. *Episodes*, **15**, 243 - 251.

Pettijohn, F.J., Potter, P.E., and Siever, R. (1972). *Sand and Sandstone*. Springer-Verlag, New York, 618 pp.

Phillips, G.N. (1988). Widespread fluid infiltration during metamorphism of the Witwatersrand goldfields: generation of chloritoid and pyrophyllite. *J. Metamorphic Geol.*, **6**, 311 - 332.

Phillips, G.N., Groves, D.I., and Brown, I.J. (1987). Source requirements for the Golden Mile, Kalgoorlie: significance to the metamorphic replacement model for Archean gold deposits. *Can. J. Earth Sci.*, **24**, 1643 - 1651.

Pisutha-Arnond, V., and Ohmoto, H. (1983). Thermal history, and chemical and isotopic compositions of the ore-forming fluids responsible for the Kuroko massive sulfide deposits in the Hokuroku District of Japan. *Econ. Geol. Mon.*, **5**, 523 - 558.

Poulson, K.H., Card, K.D., and Franklin, J.M. (1992). Archean tectonic and metallogenic evolution of the Superior Province of the Canadian Shield. *Precambrian Res.*, **58**, 25 - 54.

Pumpelly, R., Wolff, J.E., and Dale, T.N. (1894). Geology of the Green Mountains. *U.S. geol. Surv. Mem.*, **23**, 1 - 157.

Pupin, J.P. (1980). Zircon and granite petrology. *Contr. Miner. Petrol.*, **73**, 207 - 220.

Ramsay, J.G. (1963). Structural investigations in the Barberton Mountain Land, Eastern Transvaal. *Trans. geol. Soc. S. Afr.*, **66**, 353 - 401.

Ramsay, J.G., and **Huber, M.I.** (1983). *The Techniques of Modern Structural Geology. Volume 1: Strain Analysis*. Academic Press, London, 307 pp.

Ramsay, J.G., and **Huber, M.I.** (1987). *The Techniques of Modern Structural Geology. Volume 2: Folds and Fractures*. Academic Press, London, 307 pp.

Reimer, T.O. (1980). Archean sedimentary baryte deposits of the Swaziland Supergroup (Barberton Mountain Land, South Africa). *Precambrian Res.*, **12**, 393 - 410.

Richter, F.M. (1985). Models for the Archean thermal regime. *Earth Planet. Sci. Lett.*, **73**, 350 - 360.

Ricketts, B.D., Ware, M.J., and **Donaldson, J.A.** (1982). Volcaniclastic rocks and volcaniclastic facies in the middle Precambrian (Aphebian) Belcher Group, Northwest Territories, Canada. *Can. J. Earth Sci.*, **19**, 1275 - 1294.

Ridge, J.D. (1973). Volcanic exhalations and ore deposition in the vicinity of the sea floor. *Mineral. Deposita*, **8**, 332 - 348.

Robb, L.J. (1978). A general geological description of the Archaean granitic terrane between Nelspruit and Bushbuckridge, Eastern Transvaal. *Trans. geol. Soc. S. Afr.*, **81**, 331 - 338.

Robb, L.J. (1983). Trace element trends in granites and the distinction between partial melting and crystal fractionation processes: case studies from two granites in southern Africa, 279 - 294. *In:* Augustithis, S.S., Ed., *The Significance of Trace Elements in Solving Petrogenetic Problems and Controversies*. Theophrastus Publications S.A., Athens, 917 pp.

Robb, L.J., and **Anhaeusser, C.R.** (1983). Chemical and petrogenetic characteristics of Archaean tonalite - trondhjemite gneiss plutons in the Barberton Mountain Land. *Spec. Publ. geol. Soc. S. Afr.*, **9**, 103 - 116.

Robb, L.J., and **Meyer, F.M.** (1990). Uranium-bearing accessory minerals in contrasting high-Ca and low-Ca granites from the Archaean Barberton Mountain Land, 3 - 20. *In:* Augustithis, S.S., Ed., *Primary Radioactive Minerals (the Textural Patterns of Radioactive Paragenetic Associations)*. Theophrastus Publications S.A., Athens, 417 pp.

Robb, L.J., Anhaeusser, C.R., and **Van Nierop, D.A.** (1983). The recognition of the Nelspruit batholith north of the Barberton greenstone belt and its significance in terms of Archaean crustal evolution. *Spec. Publ. geol. Soc. S. Afr.*, **9**, 117 - 130.

Robb, L.J., Barton, J.M., Jr., Kable, E.J.D., and Wallace, R.C. (1986). Geology, geochemistry and isotopic characteristics of the Archaean Kaap Valley pluton, Barberton Mountain Land, South Africa. *Precambrian Res.*, **31**, 1 - 36.

Robb, L.J., Meyer, F.M., Kröner, A., Trumbull, R.B., Reimold, W.U., De Briuyn, H., Walraven, F., and Toulkeridis, T. (1993). Late-stage granite plutons in the Barberton region and Swaziland: an update. *Ext. Abstr. 16th Int. Coll. Afr. Geol., Mbabane*, 299 - 301.

Robertson, M.J. (1989). *The structural geology and gold mineralization of the Main Reef Complex, Sheba Gold Mine, Barberton greenstone belt.* M.Sc. thesis (unpubl.), Univ. Witwatersrand, Johannesburg, 127 pp.

Rock, N.M.S. (1991). *Lamprophyres.* Blackie, Glasgow, 285 pp.

Rona, P.A. (1988). Hydrothermal mineralization of oceanic ridges. *Can. Miner.*, **26**, 431 - 465.

SACS (1980). See South African Committee for Stratigraphy (1980).

Sainty, R.A. (1992). Shallow-water stratigraphy at the Mount Chalmers volcanic-hosted massive sulfide deposit, Queensland, Australia. *Econ. Geol.*, **87**, 812 - 824.

Sangster, D.F., and Scott, S.D. (1976). Precambrian, strata-bound, massive Cu-Zn-Pb sulfide ores of North America, 129 - 222. *In:* Wolf, K.H., Ed., *Handbook of Strata-bound and Stratiform Ore Deposits*, **6**. Elsevier, Amsterdam, 585 pp.

Saunders, A.D., Tarney, J., and Weaver, S.D. (1980). Transverse geochemical variations across the Antarctic Peninsula: implications for the genesis of calc-alkaline magmas. *Earth Planet. Sci. Lett.*, **46**, 344 - 360.

Sawkins, F.J. (1990). Integrated tectonic-genetic model for volcanic-hosted massive sulfide deposits. *Geology*, **18**, 1061 - 1064.

Schweigart, H., and Liebenberg, W.R. (1966). Mineralogy and chemical behaviour of some refractory gold ores from the Barberton Mountain Land. *Rep. Nat. Inst. Metall., Johannesburg*, **8**, 96 pp.

Schwerdtner, W.M., Sutcliffe, R.H., and Tröeng, B. (1978). Patterns of total strain in the crestal region of immature diapirs. *Can. J. Earth Sci.*, **15**, 1437 - 1447.

Shervais, J.W. (1982). Ti-V plots and the petrogenesis of modern and ophiolitic lavas. *Earth Planet. Sci. Lett.*, **59**, 101 - 118.

Sillitoe, R.H. (1982). Extensional habitats of rhyolite-hosted massive sulfide deposits. *Geology*, **101**, 403 - 407.

Sleep, N.H., and **Windley, B.F.** (1982). Archean plate tectonics: constraints and inferences. *J. Geol.*, **90**, 363 - 379.

South African Committee for Stratigraphy (1980). Stratigraphy of South Africa, Part 1. (Compiler L.E. Kent). *Lithostratigraphy of the Republic of South Africa, South West Africa / Namibia and the Republics of Bophuthatswana, Transkei and Venda.* Handb. geol. Surv. S. Afr., **8**, 690 pp.

Spear, F.S. (1981). An experimental study of hornblende stability and compositional variability in amphibolite. *Amer. J. Sci.*, **281**, 697 - 734.

Speer, J.A. (1982). Zircon, 67 - 112. *In:* Ribbe, P.H., Ed., *Orthosilicates.* 2nd Ed., Rev. Mineral., **5**, 450 pp.

Stacey, J.S., and **Kramers, J.D.** (1975). Approximation of terrestrial lead isotope evolution by a two-stage model. *Earth Planet. Sci. Lett.*, **26**, 207 - 221.

Steiger, R.H., and **Jäger, E.** (1977). Subcommission on geochronology: convention on the use of decay constants in geo- and cosmochronology. *Earth Planet. Sci. Lett.*, **36**, 359 - 362.

Stolz, A.J., Varne, R., Davies, G.R., Wheller, G.E., and **Foden, J.D.** (1990). Magma source components in an arc - continent collision zone: the Flores - Lembata sector, Sunda arc, Indonesia. *Contr. Miner. Petrol.*, **105**, 585 - 601.

Storey, M., Mahoney, J.J., Kroenke, L.W and **Saunders, A.D.** (1991). Are oceanic plateaus sites of komatiite formation? *Geology*, **19**, 376 - 379.

Streckeisen, A. (1976). To each plutonic rock its proper name. *Earth-Sci. Rev.*, **12**, 1 - 33.

Swinden, H.S. (1991). Paleotectonic settings of volcanogenic massive sulphide deposits in the Dunnage Zone, Newfoundland Appalachians. *Can. Min. Metall. Bull.*, **83**, 59 - 69.

Sylvester, P.J., Attoh, K., and **Schulz, K.J.** (1987). Tectonic setting of late Archean bimodal volcanism in the Michipicoten (Wawa) greenstone belt, Ontario. *Can. J. Earth Sci.*, **24**, 1120 - 1134.

Taira, A., Pickering, K.T., Windley, B.F., and **Soh, W.** (1992). Accretion of Japanese island arcs and implications for the origin of Archean greenstone belts. *Tectonics*, **11**, 1224 - 1244.

Tankard, A.J., Jackson, M.P.A., Eriksson, K.A., Hobday, D.K., Hunter, D.R., and **Minter, W.E.L.** (1982). *Crustal Evolution of Southern Africa. 3.8 Billion Years of Earth History.* Springer-Verlag, New York, 523 pp.

Tarney, J., Dalziel, I.W.D., and **De Wit, M.J.** (1976). Marginal basin 'Rocas Verdes' Complex from S. Chile: a model for Archaean greenstone belt formation, 131 - 146. *In:* Windley, B.F., Ed., *The Early History of the Earth.* John Wiley and Sons, Chichester, 619 pp.

Taylor, R.S. (1981). *Volcanogenic copper-zinc sulphide deposits and their geological setting in the central portion of the Murchison greenstone belt, northeastern Transvaal, South Africa.* Ph.D. thesis (unpubl.), Univ. Durham, England, 361 pp.

Taylor, S.R., and **McLennan, S.M.** (1985). *The Continental Crust: its Composition and Evolution.* Blackwell Scientific Publications, London, 312 pp.

Tegtmeyer, A.R., and **Kröner, A.** (1987). U-Pb zircon ages bearing on the nature of early Archaean greenstone belt evolution, Barberton Mountain Land, southern Africa. *Precambrian Res.*, **36**, 1 - 20.

Thompson, R.N., Morrison, M.A., Hendry, G.L., and **Parry, S.J.** (1984). An assessment of the relative roles of crust and mantle in magma genesis: an elemental approach. *Phil. Trans. Roy. Soc. Lond.*, **A310**, 549 - 590.

Thornton, C.P., and **Tuttle, O.F.** (1960). Chemistry of igneous rocks. I. Differentiation Index. *Amer. J. Sci.*, **258**, 664 - 684.

Tomkinson, M.J., and **King, V.J.** (1991). The tectonics of the Barberton greenstone belt - an overview, 69 - 83. *In:* Ashwal, L.D., Ed., *Two Cratons and an Orogen - Excursion Guidebook and Review Articles for a Field Workshop Through Selected Archaean Terranes of Swaziland, South Africa and Zimbabwe.* IGCP Project **280**, Dept. Geol., Univ. Witwatersrand, Johannesburg, 312 pp.

Tomkinson, M.J., and **Lombard, A.** (1990). Structure, metamorphism and mineralization in the New Consort Gold Mines, Barberton greenstone belt, South Africa. *Ext. Abstr. 3rd Int. Archaean Symposium, Perth*, 377 - 379.

Tuttle, O.F., and **Bowen, N.L.** (1958). Origin of granite in the light of experimental studies in the system $NaAlSi_3O_8$ - $KAlSi_3O_8$ - SiO_2 - H_2O. *Mem. geol. Soc. Amer.*, **74**, 153 pp.

Ujike, O., and **Goodwin, A.M.** (1987). Geochemistry and origin of Archean felsic metavolcanic rocks, central Noranda area, Quebec, Canada. *Can. J. Earth Sci.*, **24**, 2551 - 2567.

Urabe, T., and **Kusakabe, M.** (1990). Barite silica chimneys from the Sumisu Rift, Izu-Bonin Arc: possible analog to hematitic chert associated with Kuroko deposits. *Earth Planet. Sci. Lett.*, **100**, 283 - 290.

Urabe, T., and **Marumo, K.** (1991). A new model for Kuroko-type deposits of Japan. *Episodes*, **14**, 246 - 251.

Van Bergen, M.J., Vroon, P.Z., Varekamp, J.C., and **Poorter, R.P.E.** (1992). The origin of the potassic rock suite from Batu Tara volcano (East Sunda arc, Indonesia). *Lithos*, **28**, 261 - 282.

Van den Eeckhout, B., Grocott, J., and **Vissers, R.** (1986). On the role of diapirism in the segregation, ascent and final emplacement of granitoid magmas - discussion. *Tectonophysics*, **127**, 161 - 166.

Van Schalkwyk, J.F., and **Van Reenen, D.D.** (1992). High-temperature hydration of ultramafic granulites from the Southern Marginal Zone of the Limpopo Belt by infiltration CO_2-rich fluid. *Precambrian Res.*, **55**, 337 - 352.

Vearncombe, J.R. (1991). A possible Archaean island arc in the Murchison belt, Kaapvaal Craton, South Africa. *J. Afr. Earth Sci.*, **13**, 299 - 304.

Vearncombe, J.R., Barton, J.M., Jr., and **Walsh, K.L.** (1987). The Rooiwater Complex and associated rocks, Murchison granitoid-greenstone terrane, Kaapvaal Craton. *Trans. geol. Soc. S. Afr.*, **90**, 361 - 377.

Vernon, R.H. (1986). Evaluation of the "quartz-eye" hypothesis. *Econ. Geol.*, **81**, 1520 - 1527.

Vernon, R.H., and **Flood, R.H.** (1977). "Quartz-eye"-bearing porphyroidal rocks and volcanogenic massive sulfide deposits - a discussion. *Econ. Geol.*, 72, 698 - 703.

Vidal, C.E. (1987). Kuroko-type deposits in the middle Cretaceous marginal basin of central Peru. *Econ. Geol.*, **82**, 1409 - 1430.

Viljoen, M.J. (1963). *The geology of the Lily syncline and portion of the Eureka syncline between the Consort Mine and Joe's Luck Siding, Barberton Mountain Land.* M.Sc. thesis (unpubl.), Univ. Witwatersrand, Johannesburg, 131 pp.

Viljoen, M.J., and **Viljoen, R.P.** (1969a). An introduction to the geology of the Barberton granite-greenstone terrain. *Spec. Publ. geol. Soc. S. Afr.*, **2**, 9 - 28.

Viljoen, M.J., and **Viljoen, R.P.** (1969b). A proposed new classification of the granitic rocks of the Barberton region. *Spec. Publ. geol. Soc. S. Afr.*, **2**, 153 - 180.

Viljoen, M.J., and **Viljoen, R.P.** (1969c). A reappraisal of granite-greenstone terrains of shield areas based on the Barberton model. *Spec. Publ. geol. Soc. S. Afr.*, **2**, 245 - 273.

Viljoen, M.J., and **Viljoen, R.P.** (1969d). The geology and geochemistry of the lower ultramafic unit of the Onverwacht Group and a proposed new class of igneous rocks. *Spec. Publ. geol. Soc. S. Afr.*, **2**, 55 - 85.

Viljoen, M.J., Van Vuuren, C.J.J., Pearton, T.N., Minnitt, R.C.A., Muff, R., and Cilliers, F. (1978). The regional geological setting of mineralization in the Murchison Range with particular reference to antimony. *Spec. Publ. geol. Soc. S. Afr.* , 4, 55 - 76.

Viljoen, M.J., Viljoen, R.P., and Pearton, T.N. (1982). The nature and distribution of Archaean komatiites in South Africa, 53 - 79. *In:* Arndt, N.T., and Nisbet, E.G., Eds., *Komatiites*. George Allen and Unwin, London, 526 pp.

Viljoen, M.J., Muff, R., and Paizes, P. (1986). The Amo antimony deposits, Barberton greenstone belt, 349 - 357. *In:* Anhaeusser, C.R., and Maske, S., Eds., *Mineral Deposits of Southern Africa*, I. Geol. Soc. S. Afr., 1020 pp.

Viljoen, R.P., and Viljoen, M.J. (1969e). The effects of metamorphism and serpentinization on the volcanic and associated rocks of the Barberton region. *Spec. Publ. geol. Soc. S. Afr.*, 2, 29 - 53.

Viljoen, R.P., and Viljoen, M.J. (1969f). The geological and geochemical significance of the upper formations of the Onverwacht Group. *Spec. Publ. geol. Soc. S. Afr.*, 2, 113 - 151.

Viljoen, R.P., and Viljoen, M.J. (1969g). The relationship between mafic and ultramafic magma derived from the upper mantle and the ore deposits of the Barberton region. *Spec. Publ. geol. Soc. S. Afr.*, 2, 221 - 244.

Viljoen, R.P., and Viljoen, M.J. (1970). The geology and geochemistry of the layered bodies of the Kaapmuiden area, Barberton Mountain Land. *Spec. Publ. geol. Soc. S. Afr.*, 1, 661 - 688.

Viljoen, R.P., Saager, R., and Viljoen, M.J. (1969). Metallogenesis and ore control in the Steynsdorp goldfield, Barberton Mountain Land, South Africa. *Econ. Geol.*, 64, 778 - 797.

Visser, D.J.L. *(Compiler)* (1956). The geology of the Barberton area. *Spec. Publ. geol. Surv. S. Afr.*, 15, 253 pp.

Vlaar, N.J. (1986). Archaean global dynamics. *Geol. Mijn.*, 65, 91 - 101.

Waters, J.C., and Wallace, D.B. (1992). Volcanology and sedimentology of the host succession to the Hellyer and Que River volcanic-hosted massive sulfide deposits, northwestern Tasmania. *Econ. Geol.*, 87, 650 - 666.

Wendt, J.I., Toulkeridis, T., Kröner, A., and Heubeck, C. (1993). Single zircon geochronology of Archean granitoids in South Africa and Swaziland. *Ext. Abstr. 16th Int. Coll. Afr. Geol., Mbabane*, 378 - 379.

Wheller, G.E., Varne, R., Foden, J.D., and **Abbott, M.J.** (1987). Geochemistry of Quaternary volcanism in the Sunda-Banda arc, Indonesia, and three-component genesis of island-arc basaltic magmas. *J. Volcanol. Geotherm. Res.*, **32**, 137 - 160.

Whitford, D.J., McPherson, W.P.A., and **Wallace, D.B.** (1989). Geochemistry of the host rocks of the volcanogenic massive sulfide deposit at Que River, Tasmania. *Econ. Geol.*, **84**, 1 - 21.

Widenbar, I. (1976). Report on barite occurrences in the Barberton greenstone belt. *Unpubl. Rep. geol. Surv. S. Afr.*, 10 pp.

Wilks, M.E. (1988). The Himalayas - a modern analogue for Archaean crustal evolution. *Earth Planet. Sci. Lett.*, **87**, 127 - 136.

Williams, D.A.C., and **Furnell, R.G.** (1979). Reassessment of part of the Barberton type area, South Africa. *Precambrian Res.*, **9**, 325 - 347.

Williams, M.L., and **Burr, J.L.** (1994). Preservation and evolution of quartz phenocrysts in deformed rhyolites from the Proterozoic of southwestern North America. *J. Struct. Geol.*, **16**, 203 - 221.

Wilson, M. (1989). *Igneous Petrogenesis. A Global Tectonic Approach*. Unwin Hyman, London, 466 pp.

Winchester, J.A., and **Floyd, P.A.** (1977). Geochemical discrimination of different magma series and their differentiation products using immobile elements. *Chem. Geol.*, **20**, 325 - 343.

Windley, B.F. (1977). *The Evolving Continents*. John Wiley and Sons, London, 385 pp.

Windley, B.F. (1981). Precambrian rocks in the light of the plate-tectonic concept, 1 - 20. *In:* Kröner, A., Ed., *Precambrian Plate Tectonics*. Elsevier, Amsterdam, 781 pp.

Winkler, H.G.F. (1979). *Petrogenesis of Metamorphic Rocks*. 5th Ed., Springer-Verlag, New York, 348 pp.

Wood, D.A. (1979). A variably veined suboceanic upper mantle - genetic significance for mid-ocean ridge basalts from geochemical evidence. *Geology*, **7**, 499 - 503.

Wood, D.A., Joron, J.L., and **Treuil, M.** (1979). A re-appraisal of the use of trace elements to classify and discriminate between magma series erupted in different tectonic settings. *Earth Planet. Sci. Lett.*, **45**, 326 - 336.

Wright, T.O., and **Platt, L.B.** (1982). Pressure dissolution and cleavage in the Martinsburg shale. *Amer. J. Sci.*, **282**, 122 - 135.

Wronkiewicz, D.J., and **Condie, K.C.** (1987). Geochemistry of Archean shales from the Witwatersrand Supergroup, South Africa: source-area weathering and provenance. *Geochim. cosmochim. Acta*, **51**, 2401 - 2416.

York, D., Layer, P.W., López-Martínez, M., and **Kröner, A.** (1989). Thermal histories from the Barberton greenstone belt, southern Africa. *Abstr. 28th Int. Geol. Cong., Washington*, p. 3-413.

Zen, E., and **Hammarstrom, J.M.** (1984). Magmatic epidote and its petrologic significance. *Geology* **12**, 515 - 518.

Zhou, T., Dong, G., and **Phillips, G.N.** (1994). Chemographic analysis of assemblages involving pyrophyllite, chloritoid, chlorite, kaolinite, kyanite, quartz: application to metapelites in the Witwatersrand goldfields, South Africa. *J. Metamorphic Geol.*, **12**, 655 - 666.

Author: Kohler Ernst Alfred.

Name of thesis: The geology of the Archaean granitoid-greenstone terrane in the vicinity of Three Sisters, Barberton Greenstone Belt.

PUBLISHER:

University of the Witwatersrand, Johannesburg
©2015

LEGALNOTICES:

Copyright Notice: All materials on the University of the Witwatersrand, Johannesburg Library website are protected by South African copyright law and may not be distributed, transmitted, displayed or otherwise published in any format, without the prior written permission of the copyright owner.

Disclaimer and Terms of Use: Provided that you maintain all copyright and other notices contained therein, you may download material (one machine readable copy and one print copy per page)for your personal and/or educational non-commercial use only.

The University of the Witwatersrand, Johannesburg, is not responsible for any errors or omissions and excludes any and all liability for any errors in or omissions from the information on the Library website.