A fossil hot spring system in the Brandberg Complex, Damara Province, South West Africa/Namibia

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A fossil hot spring system occurs in the western foothills (Numas Valley) of the Brandberg Complex, about 150 km west of Omaruru, South West Africa/Namibia. The complex is one of a number of Jurassic to Cretaceous anorogenic ring-type complexes in the Damara Province. The fossil hot spring system, which was probably developed late in the geological history of the Brandberg Complex, is exposed over a vertical extent of 200 m and consists of a vein formed by quartz + chalcedony developing upwards into a breccia zone and a stockwork zone. Wall rocks display argillic alteration and silicification. Geochemical analyses of vein material show a slight enrichment in Au. It is concluded that fossil hot spring systems can be found in deeply eroded anorogenic ring complexes, with possible precious metal mineralization potential.

Tekens van 'n fossielwarmbronstelsel kom voor in die westelike hange van die Brandbergkompleks, sowat 150 km wes van Omaruru, Suidwes-Afrika/Namibië. Die Brandbergkompleks is een van 'n hele aantal anorogeniese ringagtige komplekse van Jurassiese tot Kryt-ouderdom wat in die Damara-provinsie voorkom. Die fossielwarmbronstelsel, wat waarskynlik teen die einde van die Brandbergkompleks se ontwikkeling tot stand gekom het, is oor 'n vertikale afstand van sowat 200 m blootgestel en bestaan uit 'n stamgedeelte gevorm deur 'n aar van kwarts and kalsedoon, wat na boontoe oorgaan in 'n breksiesone en 'n stokwerksone. Die wandgesteentes vertoon verandering na kleiminerale, asook silifisering. Geochemiese analises van die aarsteen dui op 'n effense verryking aan Au. Die afleiding word gemaak dat fossielwarmbronstelsels in diepverweerde anorogeniese ringkomplekse gevind kan word, en dat hulle moontlik met edelmetale gemineraliseer kan wees.

Introduction

During a field trip with the MSc. Exploration Geology class of Rhodes University, a fossil hot spring system was discovered in the western foot-hills of the Brandberg Complex, about 150 km west of Omaruru, South West Africa/Namibia.

The granitic Brandberg Complex is one of a number of anorogenic alkali ring-type complexes, emplaced in the Pan African Damara Belt (Miller, 1983). The complexes have ages ranging from 123 to 190 Ma (Erlank *et al.*, 1984), and are distributed within a 200-km wide and 400-km long northeast-trending zone (Figure 1). They represent deeply eroded volcanic centres containing both undersaturated and oversaturated rock types. These complexes are part of the widespread intracontinental magmatism that occurred during the Jurassic-Cretaceous along the eastern and western margins of South America and Africa, respectively. This magmatism is believed to have been focused along pre-existing lineaments reactivated during phases of the Gondwana break-up, or, along a hot spot track during rifting of the Atlantic (Marsh, 1973; Thiessen *et al.*, 1979; Morgan, 1983; Schilling *et al.*, 1985). Reviews of the anorogenic igneous activity are given in Bowden (1985) and Bonin (1986).

A comprehensive work on the geochemistry of some of the ring complexes of the Damara Alkaline Province (Marsh, 1973) was carried out by Prins (1981), and a recent review of their geology and mineralization was compiled by Potgieter (1987). Potgieter following Bowden's (1985) approach classified the ring complexes into two groups: (a) alkaline granite and syenitic, and (b) carbonatites and undersaturated. The Brandberg Complex belongs to the former.

Spatially and genetically associated with the ring complexes are zones of alteration-mineralization developed during stages of late to post-magmatic activity (alkali and H^+ metasomatism) and which in places formed deposits of Sn, W, Ta, Be, and U (Pirajno & Schlögl, 1987; Pirajno & Jacob, 1987; Potgieter, 1987).

Brandberg Complex

The Brandberg Complex forms a conspicuous circular topographic feature about 25 km in diameter, rising up to 2 000 m above the surrounding desert plain (Koenigstein, 2 573 m a.s.l). Brandberg means 'burning mountain' in German, because at sunset it takes on a pink-reddish colour due to its dominant K-feldspar content.

To this day because of its ruggedness, remoteness, and scarcity of water, the Brandberg Complex is poorly known. Early mention and limited work on the Brandberg rocks were reported by Chudoba (1930), Cloos & Chudoba (1931), Korn & Martin (1953), and Martin *et al.* (1960). An investigation of the geology and petrography of the Brandberg granites was carried out by Hodgson (1973). At the time of writing a study of the petrology of the Brandberg Complex is being undertaken by M. Diehl of the South West Africa/Namibia Geological Survey.

The general geology of the Complex (presented in Figure 2) combines Hodgson's Figure 1, Diehl's work (pers. comm., 1987), and a LANDSAT interpretation (Scene I.D.22414-08160, WRS:193-74). The Brandberg granitic rocks are intruded into Damara rocks (Kuiseb schist and granitoids) unconformably overlain by sediments and volcanics of the Karoo Sequence (Ga-Ais and Etendeka Formations, respectively). According to the interpretation on the evolution of the Complex put forward by Korn & Martin (1953), these granitic rocks

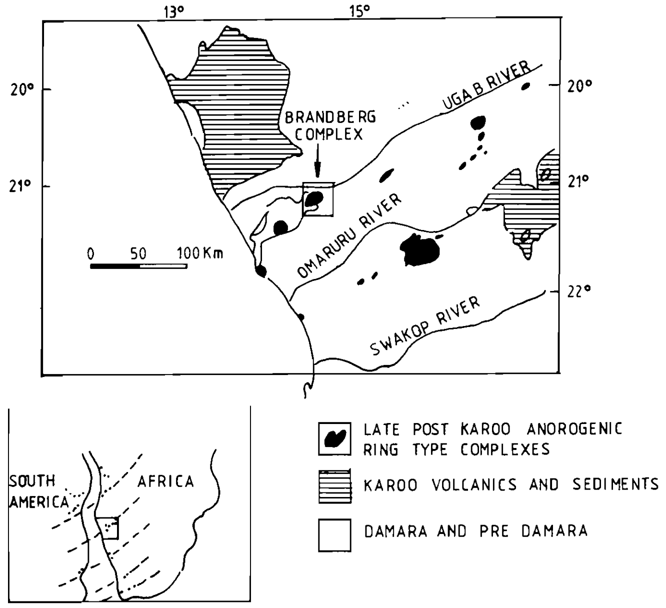

Figure 1 Locality map showing the Damara Province and anorogenic ring-type complexes. The Brandberg Complex is shown in the square. The inset illustrates the relationship of the complexes in southern Africa and South America to transform directions in the South Atlantic (after Marsh, 1973).

were passively emplaced as a result of cauldron subsidence following voluminous outpourings of felsic material. In this case the present day Brandberg would represent the deeply eroded remnant of what must have been a very large volcanic structure, perhaps similar to the Erongo caldera, a major anorogenic ring-type complex some 120 km to the southeast (Blumel *et al.*, 1979; Pirajno, 1987). The importance of the erosion level of the Brandberg Complex will become apparent later, in discussion of the fossil hot spring system. Prins (1981) proposed that the volcanics which occur as roof pendants of the Complex (Figure 2) may be part of the volcanism that was a precursor to the felsic eruptive events. Hodgson (1973) speculated that the rhyolitic rocks capping the volcanics of the Etendeka Formation to the north may be the remnants of large volumes of pyroclastic flows erupted from the Brandberg (Figure 1).

Hodgson (1973) recognized five granitic phases (Figure 2). They are : Main granite, Aegirine-augite granite, Red aplite, White aplite, and 'Brandbergite'. The last is an arfvedsonite-bearing aplitic rock (Cloos & Chudoba, 1931). To these can be added a granophyre found by the present writer as xenoliths in the Main granite. Work in progress by Diehl (pers. comm., 1987) indicates four main rock types: monzonite-syenite, quartz-syenite, riebeckite-aegirine granite, and hornblende granite (Main granite of Hodgson).

Von Knorring (1986) reported numerous varieties of alkaline granitic rocks from the Amis valley on the southwestern side of the complex. Amongst these, Von Knorring described a riebeckite-bearing granite consisting of microcline-perthite, quartz, and blue-riebeckite, set in a matrix of albite, microcline, and quartz. This granite phase was found also to contain grains of uraniferous pyrochlore (Von Knorring, 1986). The presence of riebeckite is interpreted, by the writer, as due to the interaction of post-magmatic Na-rich fluids with the primary granitic mineral assemblage (Na-metasomatism).

Numerous fractures and/or lineaments cut across the Brandberg Complex with the two major trends being west-northwest and northerly (see Figure 2). The westnorthwest-trending fractures cut across both granitic and surrounding country rocks.

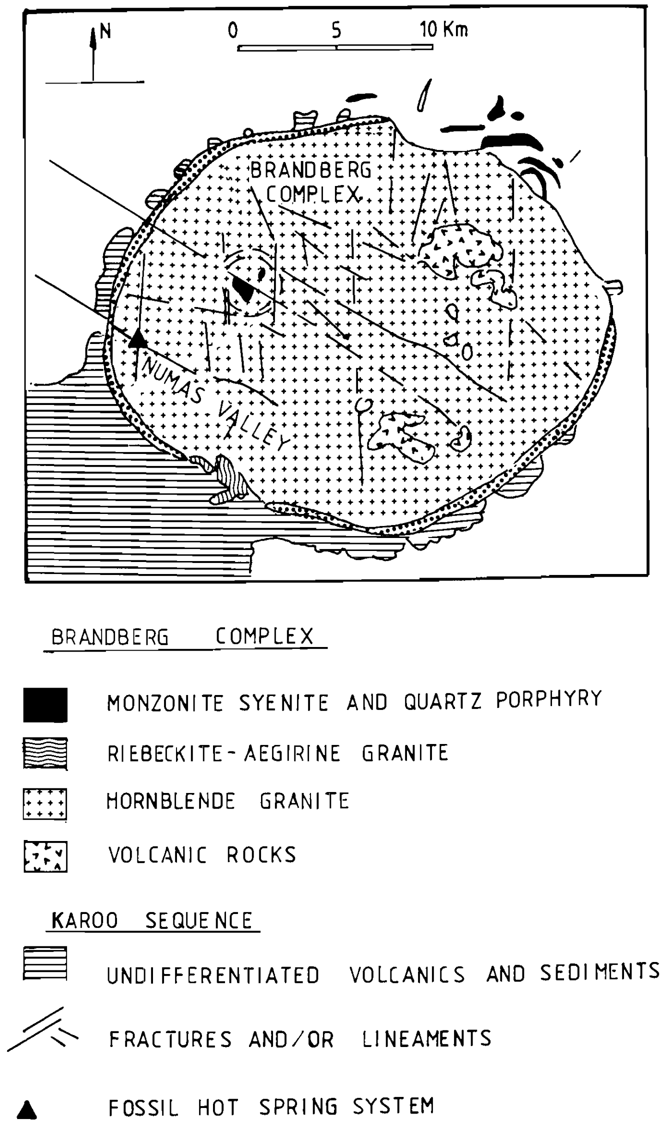

Figure 2 Schematic geological map of the Brandberg Complex, showing the location of the hot spring system. This illustration was compiled from Hodgson (1973), M. Diehl (pers. comm.), and an interpretation of LANDSAT image (see text). Damara rocks are not shown.

The fossil hot spring system

A fossil hot spring deposit occurs along Numas Valley in the western foothills of the Brandberg at the intersection of a major west-northwest fracture along which the valley is incized, and a northerly trending fracture (see Figure 2).

A schematic illustration of the structure of the exposed part of the hot spring system is shown in Figure 3. The system, although probably incomplete as the uppermost portion was eroded off (see later), is exposed on the northern side of Numas Valley over a vertical extent of about 200 m.

At valley-floor level (about 600 m a.s.l) the system is characterized by a quartz vein and minor veinlets filling west-dipping joints in hornblende granite rocks. This part of the system represents the channel way, up to 1 m thick, through which hot waters moved and deposited silica, mostly in the form of chalcedony. Argillic wall rock alteration is non-pervasive (Figure 4) and confined to within a few metres on either side of the quartz vein. In places bladed silica is present and this may be indicative of calcite replacement in a boiling zone (Buchanan, 1981). At about 700 m a.s.l. the single column develops into a stockwork zone with chalcedonic veining and a breccia zone. Limonitic and hematitic material fills open spaces and the brecciation fractures (Figure 5). This zone represents a hydrothermal breccia just above the level of postulated boiling indicated by the bladed silica.

Above the hydrothermal breccia, the stockwork increases to form a zone about 20 m wide showing selective argillic alteration of the feldspars in the wall rocks, locally overprinted by pervasive silicification (Figure 6). In places opaline quartz veinlets and finely disseminated sulphides are present. Fluidized textures in the altered wall rocks, testify to volatile escape, possibly during boiling.

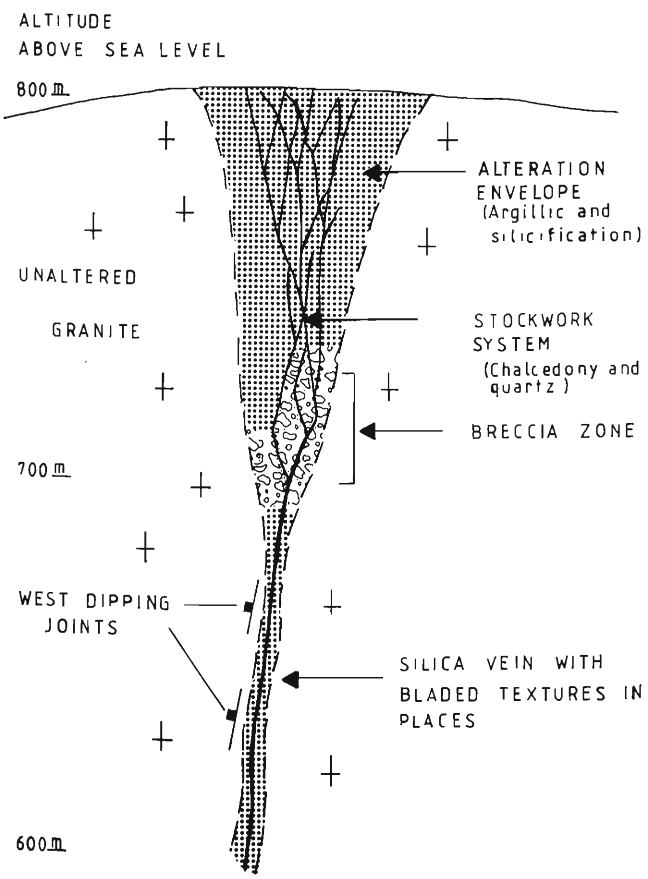

Figure 3 Schematic illustration of the exposed part of the Numas Valley fossil hot spring system.

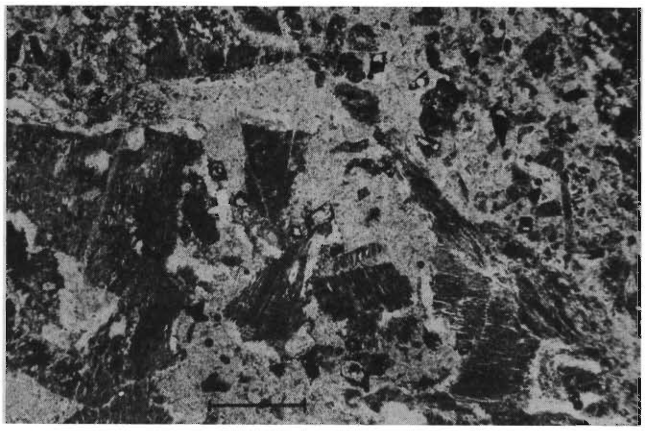

Figure 4 Argillic (dark material) alteration of feldspars (selective, non-pervasive) in wall rock Main granite. Note local granophyric texture, possibly due to post-magmatic K-metasomatism. Plane polarized light; scale bar is 0,5 mm.

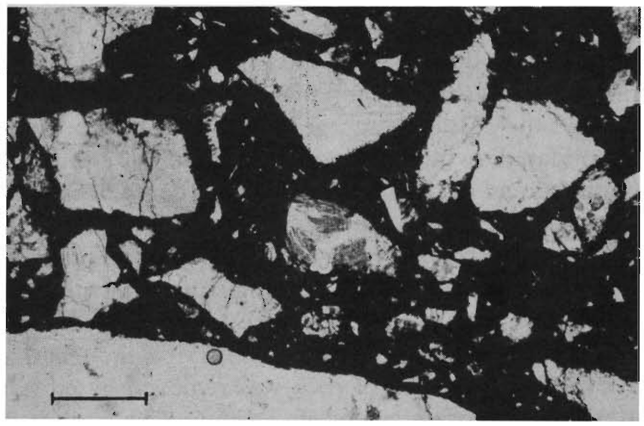

Figure 5 Breccia zone. Silicified fragments of Main granite cemented by iron oxides. This brecciation is probably the result of boiling and gas exsolution. Plane polarized light; scale bar is 0,5 mm.

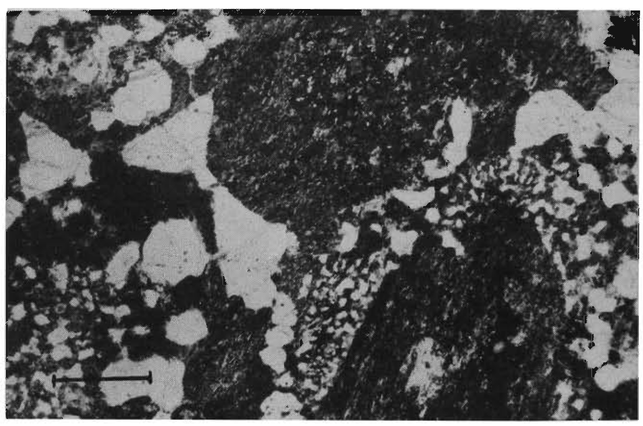

Figure 6 Stockwork zone. Fragmented argillized Main granite (dark zones) and opaline silica (light zone). Plane polarized light; scale bar is 0,5 mm.

A complete hot spring deposit is generally capped by a subhorizontal sheet of siliceous sinter material, grading downward into a silicified zone and stockwork veining (Berger & Eimon, 1982). No sinter material is present at the top of the Numas Valley fossil hot spring system, probably because it was removed by erosion. Five samples of vein material collected were submitted for metallic elements analysis. The results, shown in Table 1, indicate a slight Au-enrichment in three of the samples.

Conclusions

The occurrence of a hot spring system (see Buchanan, 1981; Berger & Eimon, 1982; Henley & Ellis, 1983) in the Brandberg Complex indicates that the joint and fracture system present in the Numas Valley area provided the necessary permeability for the waters (most probably of meteoric origin) to penetrate downward, become heated, and be channelled upward along existing joints. It can be speculated that the hot spring deposit at Brandberg is only a minor branch of a larger system centered somewhere above the present-day valley. In this area there would have been greater permeability due to the intersection of two major fracture zones (Figure 2). At the time the hot spring was active, the Brandberg granites must have been consolidated to allow the development of joints and fractures, and yet to still retain heat at depth to activate hydrothermal convection. Also, because hot springs are a surface feature, the Numas Valley system was probably formed after most of the volcanic superstructure that overlay the granite had been removed by erosion.

On the basis of the points explained, it is thought that at least 250 to 300 m of rock was removed by erosion after the hot spring ceased its activity. This is inferred because (a) boiling in hot spring deposits is believed to take place at depths of 350–400 m below surface (Buchanan, 1981); and (b) the Numas Valley occurrence is exposed along a vertical gradient of 200 m (600 to 800 m a.s.l.) with a hydrothermal breccia zone at about half way, e.g. 100 m below present-day surface.

Table 1 Metallic element analyses of vein material from the fossil hot spring system. Analyses were performed at a commercial laboratory (Rock Labs., Pretoria). All values are in ppm.

Sample No.	1	2	3	4	5
Cu	37	–3	13	8	24
Pb	34	7	12	6	13
Zn	64	12	94	11	70
Ag	–3	–3	–3	–3	–3
Au	0,12	–0,05	0,11	–0,05	0,20
W	40	–25	–25	–25	–25
Bi	–50	–50	–50	–50	–50
Mo	–10	–10	–10	–10	–10
Sn	–15	–15	–15	–15	–15

(–) denotes less than.

As indicated by the poorly developed alteration effects and the lack of significant metal values (see Table 1), the Numas Valley hot spring deposit is possibly the result of a single-pass system acting over a short period of time. The presence of a fossil hot spring system in the Brandberg granite indicates that other similar deposits possibly containing precious metal mineralization may be found in anorogenic ring complexes, even if they are deeply eroded. The plutonic rocks associated with the ring-complexes would provide the heat source necessary to drive a convection cell, although for each specific case it would remain to establish the nature and duration of the hydrothermal activity, because these are important parameters for the leaching, transport, and deposition of precious metals.

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