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The Geology of the Area Around the Khan and Swakop Rivers in South West Africa

by

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THE GEOLOGY OF THE AREA AROUND THE KHAN AND SWAKOP RIVERS IN SOUTH WEST AFRICA

ABSTRACT

A sparsely populated and arid area of some 3000 square miles located in the region of the Khan and Swakop Rivers in South West Africa, was mapped on aerial photographs during 1959 and 1960. It is underlain largely by highly folded and metamorphosed and partially granitised Damara rocks.

Two major morphological units developed under arid conditions are present: an inselberg region and the Namib Plain region. Both of these are deeply dissected by the gorges and tributaries of the Khan and Swakop Rivers which drain the area into the South Atlantic Ocean at Swakopmund.

Rocks of the Precambrian Abbabis Formation outcrop in two anticlinal cores in the area mapped. They consist largely of a quartzofelspathic gneissose group (Abbabis gneiss), a dolomitic marble and calc-silicate group, and a biotite schist group. There are also a few amygdaloidal flows included in the succession. All these rocks are invaded by a number of pegmatites and some basic igneous dykes of uralitised gabbro.

The evidence presented shows that these older rocks were already highly metamorphosed, invaded by granite and pegmatite as well as folded prior to the deposition of the Nosib Formation and the Damara System.

A description of the stratigraphy and lithology of the Nosib and Damara metasediments consisting of the mainly quartzitic Nosib Formation, the marbles of the Lower Hakos Stage, the Upper Hakos Stage also composed mostly of marbles with a tillite at the base, and the mica schists of the Khomas Series, is followed by a description and discussion of the generation, by ultrametamorphism of igneous rock-types, and the structure and its relation to metamorphism and granitisation.

The interpretation of these features, together with the mineralogical, chemical and detailed structural data derived from their investigation, is as follows:

The Nosib and Damara sediments were deposited in relatively shallow water probably between 500 and 600 million years ago. The lower arenaceous member (Etusis quartzites) was deposited in broad basins on an uneven floor in shallow turbulent waters. The sediments were immature and highly felspathic. Quieter and slightly deeper water conditions developed after the basins had been partially filled. Arenaceous sediments (Khan quartzites) were followed by argillaceous and calcareous deposition (Lower Hakos marbles) after which cold conditions, accompanied by tillite deposition, set in. After retreat of the ice, carbonate alternating with argillaceous sediments was deposited (Upper Hakos Stage) on a flat surface at moderate depths. The final and prolonged phase of argillaceous sedimentation (Khomas schists) was completed prior to the onset of tectonic deformation.

Probably a short time after sedimentation and deep burial of the sediments at present exposed, metamorphism began. It reached amphibolite grades concurrently with the onset of the first phase of fold movements which were directed by compression from the northeast and southwest. These folds eventually developed into large northwest-trending structures which were locally isoclinal and overturned to the southwest. Metamorphism and pegmatite formation continued throughout this phase as well as throughout the following intense compressional fold phase directed from the northwest and southeast, forming local strong interference patterns where early isoclinal folds existed. Metamorphism reached a peak towards the close of the second and major tectonic phase, resulting in the granitisation and local melting and mobilisation of the rocks. The felspathic quartzites of the Nosib Formation were transformed into red granite-gneisses, and the biotite schists and biotite-quartz schists of the Khomas Series overlying the marbles of the Hakos Series were transformed into quartzofelspathic biotite gneisses and granites (Salem granites and gneisses) and quartz diorite rocks. This transformation was largely isochemical. The gneissic rocks were locally mobilised and differentiated (mainly in the east) forming several intrusive dioritic, granitic and pegmatitic bodies. The Hakos marbles were only locally melted and not granitised. Temperature conditions of 600 to 650° C at a depth of about 18 km in the hottest spots at the height of metamorphism are postulated.

After the cessation of metamorphism brittle conditions, accompanied by minor fracturing and wrench faulting, set in. Pegmatitic liquid associated with volatile differentiate concentrations from metamorphic and magmatic rocks was introduced into tension-zones. Lithium-beryllium-bearing pegmatites are associated with these. This phase, followed probably shortly afterwards by uplift and erosion, completed the Damara geosynclinal cycle which is 510 ± 40 million years old.

The character of the rocks in the region mapped, indicates that they were deposited, folded and metamorphosed in the deeper portions of the Damara Eugeosyncline.

A very brief description of the Karroo sediments, extrusives and intrusives is given. The intrusive dykes trending largely north-northeast and east-northeast are mainly typical olivine dolerites emplaced in deep tensional fissures. The Karroo rocks were subsequently all but completely eroded and thin terrestrial superficial deposits were laid down over wide areas.

The economic mineral deposits which are mainly of little economic interest, are described and discussed in the light of their origin. Stratigraphic control on their localisation is marked, and thought to be due both to original sedimentary concentration of elements as well as to subsequent physical and chemical (structural, metasomatic and magmatic) controlling factors.

I. INTRODUCTION

A. General Statement

The area under review occupies a portion of western Damaraland in the region of the Lower Khan and Swakop Rivers in South West Africa. It comprises some 3000 square miles* of territory bounded roughly by latitudes 22° 00′ south in the north and 22° 30′ south in the south, and longitudes 15° east in the west and 16° east in the east. This delineation is broken by an extension in the southwest covering the region around the confluence of the Khan and Swakop Rivers, and an extension in the northeast to include the locality in which the more important mineralised pegmatites in the Karibib District occur.

Prior to the present geological survey the areas noted as extensions above had not been covered by published geological maps. The region bounded by latitudes 22° 00′ to 22° 30′ south and longitudes 15° to 16° east had been mapped in a preliminary reconnaissance fashion only. This work together with the geological surveys of the two published sheets (Omaruru and Karibib) had, however, deciphered the stratigraphy of all but the oldest sequence of rocks.

The present investigation follows on previous field-work by the author as an employee of the Anglo American Prospecting Company, largely because so many extremely interesting problems of metamorphism and petrogenesis became apparent.

B. Human Activities and Means of Communication

Apart from the town of Usakos (A. 4) the region is sparsely populated. In the west, in the Namib Desert, there are virtually no inhabitants and only a few small farms located within the gorge of the Lower Swakop River. In the

* 1 square mile = 2·59 square kilometres.

central and eastern areas there are sheep and cattle farms of large dimensions, up to ± 100 square miles (64,000 acres) in extent, though generally much less, averaging about 32 square miles. These are inhabited by Europeans with attendant Bantu and Coloured servants. Karakul sheep only are raised in the central areas bordering on the desert. In the extreme east a portion of the more densely populated Otjimbingwe Reserve 104 (C. 5) falls within the area considered. The reserve is populated by Damaras.

Usakos has a total population of 3800 (1957) of which 1500 are Europeans; it is situated on the main railway line from Walvis Bay to Windhoek and serves as a junction for the northern line to Outjo, Tsumeb and Grootfontein.

Communications are generally good. The main rail and road links between the coast at Walvis Bay and Swakopmund and the interior run through the area. In the east there are several good roads leading south from Karibib and Usakos to serve the Otjimbingwe Reserve 104 and areas lying to the south. All the farms have serviceable roads and tracks. In the arid west tracks are few and far between, but most areas are readily accessible with a four-wheel drive vehicle. Flat sand-floored tributaries of the Khan and Swakop Rivers as well as these rivers themselves, serve as ideal roadways for the type of vehicle mentioned. There are many tracks of lesser importance not shown on the map. Some of these may have already become disused.

C. Water

The area as a whole is poorly watered, as the rainfall is generally extremely low, and the " rivers " are only run-off courses and normally dry. Perennial surface-water occurs at a few points in the Swakop River and at one locality in the middle reaches of the Khan River. Owing to the salinity underground water in the latter is unpotable below a point some 11 miles* downstream from Usakos. Subsurface water in the Swakop River, however, can be relied upon as a sure source of supply at most places. In areas away from the main rivers and east of the desert where most bore-hole water is undrinkable, underground water tapped by means of bore-holes and windmills (generally) forms the chief source of supply. This may be supplemented by short-lived supplies of rain-water from episodic showers. Borehole water here is generally saline though potable. In the western regions, in the Namib, drinking-water can be obtained from railway sidings, the Swakop River, Walvis Bay or Swakopmund.

D. Previous Work

That this area is of great geological interest has been known since the last century, but very little intensive geological work was done until 1929. Granite-gneisses in the Lower Khan Gorge were briefly investigated by Pechuël-Loesche in 1886 (Wagner, 1916, p. 34) and by Wulff (1887). Wulff also referred to the petrography of the quartz diorites south of Karibib. The chief interest, however, lay in the mineral occurrences, chiefly of copper, discovered late in the last century.

Voit and Stollreither first described the Khan copper-mine in 1904, and Voit (1904) the Pot and Ubib Mines, giving lateral secretion from the surrounding rocks in which the elements had been precipitated during sedimentation, as the theory of origin. A large number of investigators made

* 1 mile = 1·609 kilometres.

reference to the geology and mineral occurrences of this area between 1904 and 1929. Stutzer (1914) again described the Khan Mine, later to be studied in greater detail by Söhnge (1939). Range produced in 1912 a coloured map which does not include the area under discussion, but proved useful to early workers such as Wagner who published his extensive work on " The Geology and Mineral Industry of South-West Africa " in 1916. In this he made many references to mineral occurrences and rock-types in this area. At this time the Pre-Nama rocks were still classified as belonging to the Fundamental Complex comprising gneiss, a schist formation and " intrusive older granites " (Wagner, 1916, p. 33). Further reference to mineral deposits were made by Wagner in 1921 and Reuning in 1923; the latter also made the most notable contribution towards the knowledge of the distribution of the main rock-types of the Basement Complex which he showed on a geological map of the central portion of South West Africa to a scale of 1:2,000,000. Investigations by Cloos in the Erongo added to the knowledge of the younger formations in 1919; and by 1929, following on an attempt by Beetz (1929) to set up a stratigraphic sequence within the Fundamental Complex, the stage was set for more detailed investigations on a regional scale in this portion of western Damaraland.

Detailed mapping in the region commenced in 1927 when the Erongo tin-fields were first investigated by Haughton, Frommurze and Gevers. This work, supplemented by that of Schwellnus and Rossouw, was published in several units of papers and finally as Geological Survey Sheets 71 (Omaruru) and 79 (Karibib). This joint work, together with that by De Kock (1934) in the Rehoboth area, laid the foundation for a more detailed knowledge of the geology of western Damaraland, particularly the stratigraphic succession within the Damara System as well as its structural pattern and intrusives.

In 1929 to 1930, Gevers (1931, 1934 and 1936) extended his work across the Khan and Swakop Rivers to latitude 23° south, establishing the occurrence of a tillite horizon within the Damara System (1931a) and showing the presence of an underlying unconformably group of rocks (Abbabis Formation). Nine sheets covering latitudes 22° to 23° south and longitudes 15° to 16° east were published in 1934 (Gevers, 1934). These maps, together with the accompanying descriptions of stratigraphy, tectonics and intrusives, proved a useful basis for further more detailed work.

Following this period of regional study the area received little attention apart from mineralogical and economic investigations. In 1935 Ramdohr published his mineralogical studies of the Arandis tin-mine (Stiepelmann's Claims). In 1944 and 1946 Nel followed with investigations of pollucite, petalite and amblygonite from pegmatites in the Karibib District, and finally in 1955 Cameron, after a brief visit, wrote on the internal structure of some pegmatites in the Karibib District.

Investigations made by various mining concerns have not been published. These include the prospecting of mineral occurrences (Khan Mine, Henderson Mine, etc.) as well as of large areas. During 1956 to 1957 the Anglo American Prospecting Company mapped some 600 square miles in the Lower Khan Gorge area during a successful search for uranium deposits. The resulting map (Hyman et al., 1957) to a scale of 1:125,000 in the surveying of which the author took an active part, was used extensively in the compilation of the most southwesterly corner of the present map.

E. Present Investigation

As previously mentioned, the present investigation follows on earlier field-work carried out by the author as an employee of the Anglo American Prospecting Company.

The area, bounded by latitudes 22° and 22° 30′ south and longitudes 15° and 16° east, and its extensions were chosen because of its interesting geology and high percentage of rock outcrop. It was also thought that a more detailed and accurate map of this area would be suitable for publication by the Geological Survey, thereby extending the coverage of the regional maps to a scale of 1:125,000 to the south of the Omaruru and Karibib Sheets.

Mapping of the area was completed on aerial photographs in 1960. The Lower Khan Gorge was mapped on an uncontrolled mosaic to a scale of 1:24,600 compiled by the Anglo American Corp., Ltd. and the remainder on 12 uncontrolled mosaics to a scale of 1:36,000 compiled by the author. For detailed structural mapping in the Khan Mine area photo enlargements to a scale of 1:12,300 were used.

After completion of the field-work, the field-sheets covering the mosaics were reduced photographically on to a farm-boundary map to a scale of 1:100,000 of the Trigonometrical Survey, which did not cover the extreme west of the area. Here ground control was obtained by plane-table survey by the author. The resulting map is therefore not completely accurate trigonometrically, especially in sectors D. 1 and D. 2.

No large-scale topographical maps of the area exist. The best obtainable are plane-table maps to a scale of 1:100,000 compiled by the Topographical Section, General Staff Intelligence of the Union Defence Force in 1914, from older German maps. These are of insufficient accuracy for base-map use, but place-names and spot heights were taken from them. These maps do not cover the western portion of the area.

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II. PHYSIOGRAPHY

Climate, drainage, vegetation and morphology are only briefly dealt with here. For a more detailed account readers are referred to the relevant publications by Gevers (1936) and Logan (1960).

A. Climage, Drainage and Vegetation

The climate of the area is generally arid, more so in the west (Namib Desert) than in the east. The average annual rainfall varies from 16·51 mm* p.a. (over 20 years) at Swakopmund to 51 to 102 mm in the central areas and

* 1 millimetre=0·0394 inch.

to about 102 to 152 mm in the east (Logan, 1960, p. 10–13). Apart from precipitation from the frequent fog in the immediate coastal belt, rainfall, if any, is generally confined to the summer months November to March when it is usually restricted to short-lived downpours. Drought years are common.

At Swakopmund the average temperature for the months December to March, for a 20-year period, was 16·67° C (62° F) and for the remaining months 13·89° C (57° F). As a result of the cold off-shore Benguella Current the climate is generally cold and damp. Fog generated by the ocean current is occasionally driven as far as 80 miles inland by westerly breezes. " Trade winds " from the south are predominant during October to April. High temperatures on the coast in winter are associated with easterly " föhn " winds originating on the cold interior plateau. Temperatures rise away from the coast, especially in the river canyons where the heat is often excessive at midday. At night temperatures are generally moderate but may, in winter, fall below freezing point.

The whole of the area, with one exception, is drained by the Khan and Swakop Rivers and their tributaries. The area west of the watershed extending from Rössing Mountain (D. 1) to Ebony (B. 3) is drained directly towards the coast. The main rivers merely represent run-off courses from precipitation in the interior. Seldom does water flow in the Khan and Swakop Rivers for more than a few days, but subsurface water is always present at shallow depths.

Vegetation changes from the coast to the interior. Apart from dry river-beds with shallow ground-water, the western areas are almost devoid of vegetation. The only shrubby plants found on the desert flats are *Zygophyllum stapfi* and *Arthraeura leubnitziae*. Besides these the commonest plants here are mesembryanthemum, lithops, aerva and Bushman's candle (*Sarcocaulon burmanni*). *Welwitschia bainesii* abounds on the sandy flats around Welwitsch (D. 2). In the eastern transition-zone where the Namib merges gradually with the bush-clad country of the interior, xerophytic plants such as *Euphorbia gregaria* and *E. virosa*, are found in great abundance. The large aloe (*Aloe dichotoma*) is also quite common. In the east and in the beds of the major rivers larger trees and green shrubs are found. These include the ana (*Acacia albida*), seldom found in the west, camel-thorn (*Acacia giraffae*), bastard camel-thorn (*Acacia maras*), shepherd's-tree (*Boscia pechuela*), hook-thorn (*Acacia detinens*), leadwood, etc. The tamarisk (*Tamarisk austroafricana*) and the bright-green pungent bush locally known as the " waterbos " (*Salvadora persica*) as well as the tsawis bush (*Euclea pseudebenus*) commonly occur in the river-beds.

The contrast in vegetational cover between the run-off slopes or " veld " and the watercourses is always great. The larger types of trees mentioned above are confined exclusively to the shallow ground-water areas of the major river-beds. After good rains the grass cover is quite substantial and sufficient to support sheep and a fair-sized cattle population in the eastern areas.

B. Morphology

The area under review includes two well-defined morphological units (see pl. I, II and III). A third unit comprising the Great Escarpment is not prominent here, but is manifest to the south as the west-facing scarp of the Khomas Hochland.

1. THE INSELBERG REGION

This is the major morphological unit here and consists of extensive flats covered with variable thicknesses of superficial deposits through which the underlying rocks project to form prominent hills and mountains. The best examples of inselbergs within the area are Rössing Mountain (D. 1), the Otjipatera (B. 4) and Chuos (C. 3–4) Ranges, though these are not as spectacular as the single well-marked mountain " islands " such as the Gross Spitzkoppe and Erongo Mountains to the north of the area.

The inselberg region as well as the Namib Plain are modified by the drainage of the Khan and Swakop Rivers which are generally deeply incised and bordered by highly eroded and rugged " bad land " areas. Here the younger drainage-pattern and other morphological features are greatly influenced by the rock structure. The maximum depth of incision of these sand-filled canyon floors is about 600 feet* in the Khan River near the Khan Mine (D. 1).

2. THE NAMIB PLAIN

Reaching from the coast some 70 miles inland, this plain rises rapidly with a convex slope to an elevation of some 3600 feet northeast of Ebony (B. 3).

The Namib Plain as such is not very well developed in this area owing largely to the incision of the major rivers. It is best exemplified in the northwest around the Arandis tin-mine (B. 2) and to the south of the lower reaches of the Khan (C–D. 2) and Swakop Rivers (C. 1). This plain, largely covered by superficial deposits, is not an absolute one in that it is transgressed by long, low dolerite and marble ridges. This feature, together with the evidence of terrestrial fluviatile gravel deposits over wide areas, supports the view that the plain is not of marine origin (Wagner, 1916, p. 72; Gevers, 1936, p. 17).

The age and history of these morphological features will be dealt with in a later chapter on stratigraphy and lithology. The geomorphology is typically that developed by arid-cycle erosion and has been adequately described by Gevers (1936, p. 61–79), King (1951, p. 88–97 and 318–322) and Logan (1960).

III. GENERAL GEOLOGY

The area is underlain by rocks and deposits varying in age from Precambrian to Recent. Amongst these the Precambrian formations are by far the most important. Karroo strata are represented by only two small outliers, and the Tertiary and Recent deposits form only terraces and thin superficial covers on the ubiquitous, highly metamorphosed Precambrian rocks.

Amongst the Precambrian formations three major successions have been distinguished. They are from the oldest to the youngest: Abbabis Formation, Nosib Formation and Damara System. The Abbabis Formation is separated from the younger rocks by a phase of metamorphism, granitisation and pegmatite intrusion. The quartzitic Nosib Formation is, in the area under discussion, conformably overlain by the Damara sediments, but is in other areas separated from them by a discordance passing locally into an angular unconformity.

* 1 foot = 0·3048 metre.