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THE GEOLOGY AND GEOCHEMISTRY OF SOME EPIGENETIC URANIUM DEPOSITS NEAR THE SWAKOP RIVER, SOUTH WEST AFRICA

by

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ABSTRACT

This study comprises a geological and geochemical investigation of the uranium deposits in the region near the Swakop River which extends from the Langer Heinrich Mountain in the east to the end of the Tumas River in the west, and part of the region between the Khan and Swakop Rivers. The Langer Heinrich area, which includes the Bloed=koppie Flats, Gawib River Valley and surrounding regions totalling 180 km^2 in size, was mapped in detail.

Most of the area is covered by superficial deposits which unconformably overlie basement rocks of the Nosib and Swakop Groups. It is proposed that the informal term Namib group be used to include all these rocks, which were further subdivided into the chronostratigraphic Langer Heinrich calcrete and Tumas gypcrete formations. The Gemsbok calcrete formation unconformably overlies the Langer Heinrich calcrete formation.

The general geology of the basement rocks in the Langer Heinrich region only is discussed. The main litholo=gical units present are the Etusis, Chuos and Tinkas Formations; remaining rock types are the Salem, Bloedkoppie, Gawib and Horebis Granites and pegmatites. The Bloedkoppie Granite, which shows cross-cutting features to the Tinkas and Etusis Formations, is the main granite found in the area. Unusual weathering features are characteristic of the Bloedkoppie Granite, in which alveoles and tafoni are developed.

The general geology of the younger duricrust formations is discussed. These were deposited on a palaeotopographic base of Post-Gondwana and African erosion surface age. The duricrust deposits consist mainly of siliceous fluviatile clastic material that was cemented by calcite, carnotite and/or gypsum. Three genetic varieties of calcrete are represented at the Langer Heinrich, viz calcified breccia-conglomerate, hardpan calcrete and boulder calcrete. Gypcrete is classified in a similar manner into powder gypcrete, vuggy gypcrete and consolidated gypcrete. Towards the west of the area the proportion of gypsum with respect to calcite increases, which seems to be a function of aridity.

In the Gawib River Valley two phases for the precipitation of calcite were found, the first taking place on a much larger scale than the second and the precipitation of carnotite being concurrent with the latter phase. The precipitation of carnotite and the shape of the ore-body were governed primarily by the height and profile of the water-table above the basement rocks.

The epigenetic deposits in the Tumas River Valley were classified into two types, the Tumas and Langer Heinrich Types, with the former related to negative magnetic anomalies in the basement rocks. The geology of the anaerobic basins situated off the coast at Walvis Bay is discussed. These contain diatomaceous mud.

Analytical methods were developed for the separation of thorium, protactinium and uranium from geological materials using various chromatographic procedures. The basic techniques

were modified and adapted as required for the selective separation and purification of uranium from calcite. Alpha spectrometry, neutron activation analysis and delayed neutron counting were the main techniques used.

The occurrence of uranium in the region of study follows a unique geochemical cycle, and the geochemistry at each stage in the cycle was examined. The first stage in the uranium-geochemical cycle was the basement rocks. The rare-earth distribution between these rocks provided evidence concerning their paragenesis, and indicated that the Gawib and Bloedkoppie Granites were the result of partial melting of the Etusis Formation; also, that they are late-syntec= tonic in age.

The second stage in the geochemical cycle of uranium was the subsurface water. Predictions regarding mineral equilibria could be made from the chemical composition of the water. It was found that the uranium minerals soddyite and carnotite were the stable phases in this environment. From the prospecting aspect, 30 ppb uranium were considered anomalous, while values below this were regarded as back= ground.

The third stage in the geochemical cycle of uranium concerns its occurrence in the duricrust deposits. The segregation of carnotite at the Langer Heinrich was brought about by upward diffusion of dissolved uranium caused by soil suction, and was precipitated by the nucleation of the uranyl cation on montmorillonite, and subsequent complexing with vanadate ions. Mechanisms for the formation of calcrete

and gypcrete are discussed. A new mechanism for the precipi=tation of gypsum is proposed which resulted mainly from the precipitation of calcium sulphate brought in by onshore fogs.

Isotopic disequilibrium measurements showed that uranium is still migrating, and that the age of the carno=tite precipitation is 30 000 years, based on the open-system model of uranium migration.

In the final stage of the geochemical cycle, the geochemistry of uranium in seawater and the diatomaceous muds is discussed. Organic matter was the main precipita=ting agent of uranium from seawater, and its heterogeneous distribution is due to selective uptake by particular organic compounds.

A classification system for the uranium deposits near the Swakop River, based on genetic relationships, is proposed and described in terms of the geochemical cycle of uranium, the mode of transport and mode of deposition. The relationships between the duricrust uranium deposits and the other uranium deposits of South Africa are compared.

SAMEVATTING

Die studie dek 'n geologiese en geochemiese ondersoek van die uraanafsettings in die omgewing van die Swakoprivier wat van die Langer Heinrich-gebergte in die ooste tot aan die einde van die Tumasrivier in die weste strek, asook 'n deel van die gebied tussen die Khan- en Swakoprivier. Die Langer Heinrich-gebied wat die Bloedkoppievlakte, die Gawibrivier=vallei en die omliggende gebiede behels, het 'n totale oppervlakte van 180 km^2 en is in besonderhede gekarteer.

Die grootste gedeelte van die gebied word deur oppervlakafsettings beslaan wat gesteentes van die Nosib- en Swakopgroep diskordant oordek. Daar word voorgestel dat die informele term Namibgroep gebruik word om al dié soorte gesteentes te omvat wat verder in die chronostratigrafiese Langer Heinrich-kalkreet- en Tumas-gipskreetformasie onder=verdeel is. Die Gemsbok-kalkreetformasie oordek die Langer Heinrich-kalkreetformasie diskordant.

Slegs die algemene geologie van die bodemgesteentes in die Langer Heinrich-gebied word bespreek. Die belang=rikste litologiese eenhede is die Etusis-, die Chuos- en die Tinkasformasies. Die oorblywende rotstipes is die Salem-, Bloedkoppie-, Gawib- en Horebisgraniete en -pegma=tiete. Die Bloedkoppiegraniet wat intrusiewe verhoudings ten opsigte van die Tinkas- en Etusisformasies vertoon, is die belangrikste graniet wat in die gebied gevind word. Buiten=gewone verweringseienskappe is kenmerkend van die Bloed=koppiegraniet waarin heuningkoekholtes en tafoni ontwikkel is.

Die algemene geologie van die jonger hardebank= formasie word bespreek. Hulle is op paleotopografiese vloer van na-Gondwana- en Afrika-erosieoppervlakouderdom afgeset. Die hardebankafsettings bestaan hoofsaaklik uit silika= houdende fluviale klastiese materiaal wat deur kalsiet, karnotiet en/of gips aanmekaar geheg is. Drie genetiese variëteite van kalkreet kom in die Langer Heinrich voor, naamlik verkalkte breksiekonglomerate, hardebankkalkreet en rolblokkalkreet. Gipskreet word op dieselfde wyse in poeiergipskreet, kristalholtegipskreet en gekonsolideerde gipskreet ingedeel. Na die weste van die gebied styg die verhouding van gips tot kalsiet wat 'n funksie van dorheid skyn te wees.

In die Gawibriviervallei is twee fases vir die presipitering van kalsiet gevind. Die eerste het op 'n baie groter skaal as die tweede plaasgevind en karnotiet is gelyktydig met die laaste fase gepresipiteer. Die presipitering van karnotiet en die vorm van die ertsliggaam is hoofsaaklik deur die hoogte en profiel van die grond= watervlak bokant die bodemgesteentes bepaal.

Die epigenetiese afsettings in die Tumasriviervallei is in twee groepe ingedeel, naamlik die Tumas- en die Langer Heinrich-tipes. Eersgenoemde is aan die negatiewe magnetiese anomalieë in die vloergesteentes verwant. Die geologie van die anaërobiese bekkens van die kus van Walvisbaai word bespreek. Hulle bevat diatomeëslik.

Analitiese metodes vir die skeiding van torium, protaktinium en uraan uit geologiese materiaal is ontwikkel waarin verskeie chromatografiese prosedures gebruik word.

Die basiese tegnieke is na vereiste vir die selektiewe skeiding en suiwering van uraan uit kalsiet gewysig en aangepas. Alfaspektrometrie, neutronaktiveringsanalise en vertraagdeneutron-telling was die belangrikste tegnieke wat gebruik is.

Die voorkoms van uraan in die omgewing van die studie word deur 'n unieke geochemiese siklus bepaal en die geochemie is in elke stadium van die siklus ondersoek. Die eerste stadium in die geochemiese siklus van uraan is die bodem= gesteente. Die verspreiding van seldsame aarde tussen die gesteentes het bewyse aangaande hulle paragenese gelewer en het ook aangedui dat die Gawib- en Bloedkoppiegraniete die gevolg is van gedeeltelike smelting van die Etusisformasie, en ook dat hulle laat-sintektonies in ouderdom is.

Die tweede stadium in die geochemiese siklus van uraan is die ondergrondse water. Voorspellings oor mineraal= ewewig kon uit die chemiese samestelling van die water gemaak word. Daar is gevind dat die uraanminerale soddiet en karnotiet die stabiele fases in die omgewing was. Uit 'n prospekteeroogpunt beskou, is 30 dpb uraan as 'n anomalie beskou, terwyl waardes laer as hierdie syfer as agtergrond beskou is.

Die derde stadium in die geochemie van uraan hang saam met sy voorkoms in die hardebankafsettings. Die afskeiding van karnotiet in die Langer Heinrich is die gevolg van die opwaartse diffusie van opgeloste uraan deur grondsuiging. Die uraan is hierna deur kernvorming van die uranielkatioon op montmorilloniet en daaropvolgende

kompleksvorming met vanadaatione gepresipiteer. Meganismes vir die vorming van kalkreet en gipskreet word bespreek. 'n Nuwe meganisme vir die presipitering van gips word aan die hand gedoen. Dit het hoofsaaklik uit die presipitering van kalsiumsulfaat ontstaan wat deur mis van die kus af ingebring is.

Die onewewig in isotoopsamestelling van die uraan toon dat uraan nog steeds migreer, en dat die ouderdom van die karnotietpresipitering 30 000 jaar is, indien 'n oop sisteem vir die migrering van uraan aanvaar word.

In die finale stadium van die geochemiese siklus word die geochemie van uraan in seewater en in die diatomeëslik bespreek. Organiese materiaal was die belangrikste presipi= teermiddel van uraan uit seewater, en sy onreëlmatige ver= spreiding is aan selektiewe opname deur sekere organiese verbindings toe te skrywe.

'n Indeling op grond van genetiese verwantskappe word vir die uraanafsettings naby die Swakoprivier voorgestel en word in terme van die geochemiese siklus van uraan, en die transport- en afsettingsmetode beskryf. Die verwantskappe tussen die hardebank- en die ander uraanafsettings van Suid-Afrika word vergelyk.

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