THE GEOLOGY OF MALHA CRATER (DARFUR, SUDAN)

La géologie du cratère Malha (Darfour, Soudan).

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RESUME

Cet article donne un bref aperçu de l'histoire géologique du cratère d'explosion près de Malha. Les données sont basées sur l'observation des différentes roches en affleurement dans le cratère : les roches plutoniques du socle précambrien, les sédiments détritiques des "Nubian Sandstones", les paléosols tertiaires, les coulées de lave, les dépôts pyroclastiques et les formations lacustres récentes du fond. Leurs relations et leur évolution géomorphologique sont discutées.

Abstract

A brief review of the geological history of the Malha explosion crater is given in this paper. It is based on the observation of the outcrops of the various rocks visible in the crater wall : plutonic Basement rocks, Nubian Sandstone detrital sediments, tertiary paleosols and lava sheets, pyroclastics, and recent lake deposits. Their relationship and geomorphological evolution are the subject of this study.

Malha Crater is an explosion crater with an average depth of about 100 m and a diameter of 1 kilometer in the area known as the Meidob

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Hills, situaded at about 200 km NNE of El Fasher, capital of the Darfur Province (NW Sudan). It is not the only crater of that kind in this volcanic district, but it seems to be the only one characterized by a permanent lake throughout the year. Its steep inner slopes, though often covered in their lower parts by a chaotic layer of boulders, offer an exceptional vertical cross section through the different rock strata, thus permitting a look into the geological past of this poorly known part of Africa

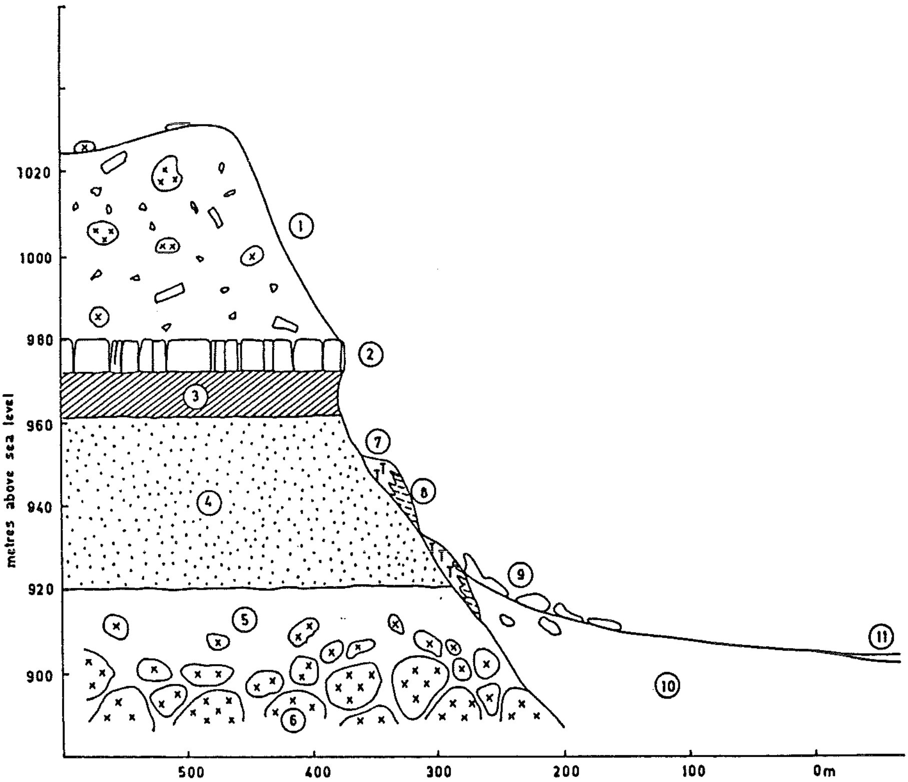


Fig. 1 : Geological Cross Section through the Wall of Malha Crater (Measurements by M. De MULDER, unpublished).

1 : pyroclastics,
2 : plateau basalt,
3 : palaeosol complex,
4 : Nubian Sandstone complex,
5 : kaolinized Basement,
6 : granitic Basement,
7 : lime sinter (travertine),
8 : diatomite,
9 : talus slope (huge boulders of various material),
10: detrital sand, gravel, volcanic ash, lake bottom sediments,
11: present crater lake.

The oldest rocks in the crater are of granitic origin (fig.1). They belong to the Precambrien African Shield. The outcrops of this so-called "Basement" are visible in the lower 20 metres of the crater; they are partly hidden by the sand deposits of the lake shore and the talus slopes at the foot of the crater walls. They clearly show evidence of a very strong chemical weathering (mainly feldspar hydrolysis) which turned the rock into an almost pure whitish kaolinite clay, containing various spheroidal blocks of less weathered granite. It can be expected that this kind of weathered zone may reach in depth a thickness of several tens of metres before the fresh rock is met. Indeed the weathering appears to have taken place in depth under influence of the groundwater table; no erosion processus has ever removed the unsoluble final weathering products. The weathered kaolinized Basement shows a regular and more or less horizontal upper boundary.

On top of it lies the so-called Nubian Sandstone Complex. The thickness of these grayish-white sediments amounts to 30 or 40 metres; as such, it is the main unit visible in the crater walls. Coarse as well as fine sandstone is by far the dominant material; some clay and carbonates locally may be present. A superficial investigation did not reveal the presence of any fossil ; it is not known whether this complex is of continental or marine origin. Its age may vary from Upper Carboniferous to Upper Cretaceous on the analogy of similar complexes known all over North-East Africa (Sudan, Egypt, Lybia).

The upper three to four metres of this detrital sedimentary unit show a completely different character. Their dominant colour is brown to reddish-brown and they mainly consist of clay, silt, sand and quartz gravel layers, probably mixed with some volcanic ash deposits (fig. 2). This whole complex should be interpreted as a succession of terrace deposits separated by at least three palaeosols developed in silty clay partly derived from volcanic ashes. The predominant clay minerals are smectite, illite and some kaolinite. The abundance of swelling clay minerals (smectite) is responsible for the destruction of most palaeopedofeatures by internal stress. Under the microscope these layers show different types of striated b-fabric in the fine groundmass. They also include an important detrital quartz fraction (a decay product from the Nubian Sandstone), and some volcanic rock fragments (fig. 3 a). Locally,

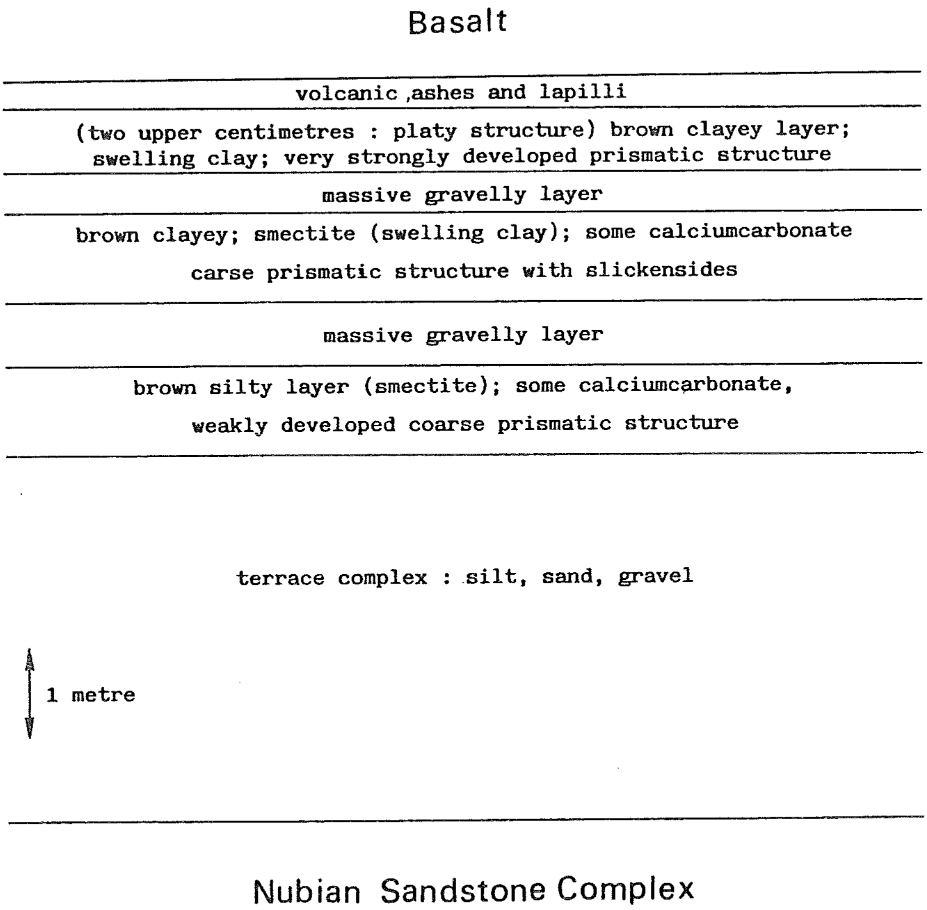


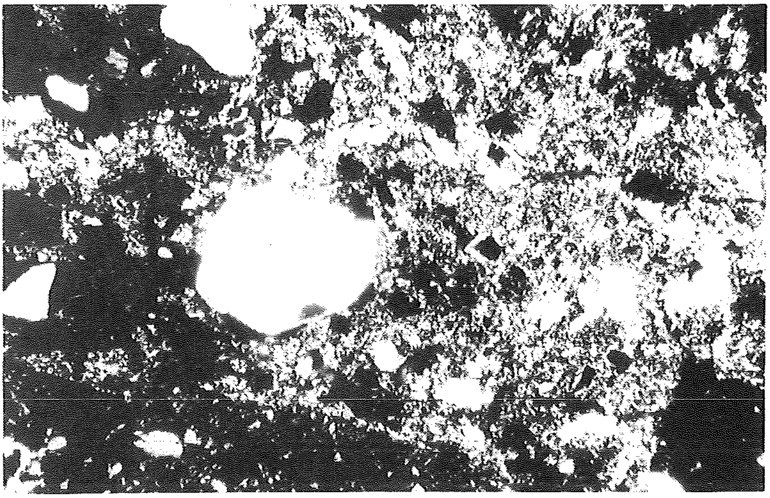
Fig. 2 : Situation of the Palaeosols between the Nubian Sandstone and the Plateau Basalt.

oriented clay fragments (disrupted papules), calcite neoformations and diffuse ferruginous nodules occur. The latter show evidence of former humid conditions prevailing in these soils. It may be presumed that this pedogenesis took place in Mid-Tertiary times, for the palaeosol-complex is covered by five to ten metres of plateau basalt, traditionally considered as a Miocene-Pliocene outflow related to the Red Sea area plate tectonics.

The outcrops of this dark, roughly columnar basalt layer correspond to the almost vertical parts of the crater wall (fig. 3 b). Its petrographical characteristics will be studied in a separate publication dealing in detail with the volcanic activity of the district. It seems that the basalt sheet resulted from a fissure effusion; indeed, a vertical fissure (dyke) with a width of several metres is running across the crater with a WSW-ENE orientation and its basaltic infilling looks connected to the plateau basalt. The surface of the latter has been subjected to pedogenesis, for locally a thin red weathering clay can be observed between the prismatic columns. Its age could be Late Tertiary or Early Pleistocene.

The upper part of the crater wall consists of a roughly stratified mass of pyroclastic materials accumulated by the explosion creating the actual crater. Its thickness may reach more than 40 metres at the rim of the crater; on the plateau it gradually decreases. These pyroclastics are mainly composed of lapilli, ashes, sand, volcanic bombs and broken fragments of the plateau basalt. Very striking is the presence of many spheroidal granitic boulders, obviously coming from the underlying kaolinized Basement. Yet blown-out Nubian Sandstone blocks are almost absent : the relatively soft sandstone has been completely pulverized into dust and sand. It is clear that the original explosion had a phreatomagmatic character. The groundwater table, situated in the lower part of the porous Nubian Sandstone Complex and in the kaolinized top of the impervious granitic Basement, has been turned into a gigantic "steam-bomb" by a sudden local magmatic intrusion right through the Basement. Though this intrusion triggered the explosion - or eventually a sequence of explosions - it did not produce any real outflow of lava.

The sudden creation of the Malha crater must have taken place at the end of the Tertiary or in the Early Pleistocene. In any case, the classical volcanic activity in the area was not yet extinct at that time : the nearby volcano Jebel Sowidor has been producing extensive ash fields and subrecent basaltic flows (fig. 3 c). One of these even spilled over the Malha crater rim and flowed down into the bottom, where it a -



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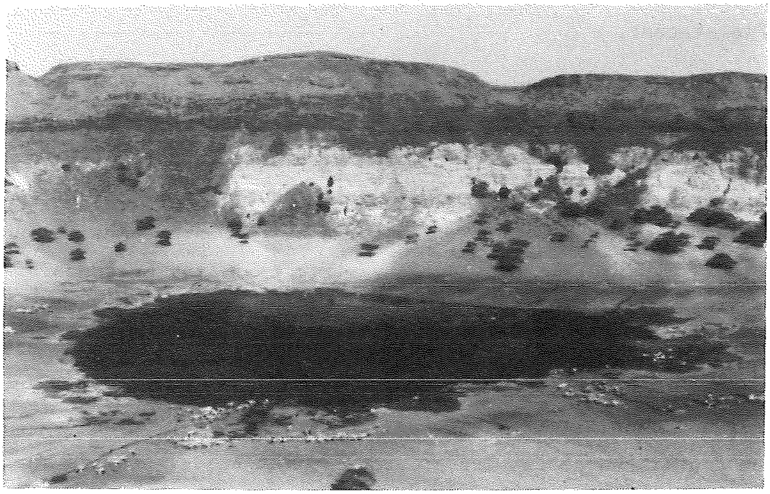

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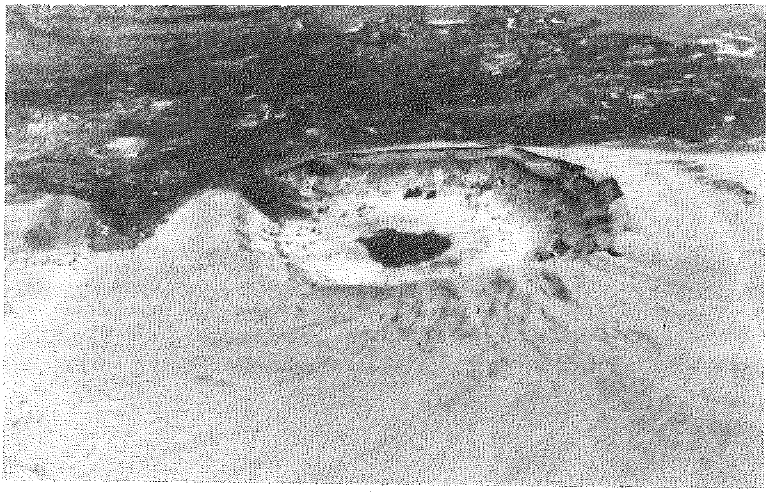

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Fig. 3 : a) Photomicrograph of palaeosol material (crossed polarizers).
Groundmass with mosaic-speckled to granostriated and reticulate striated b-fabric. Coarse fraction consisting of detrital quartz (white to gray) and volcanic rock fragments (dark heterogeneous masses). Magnification about 60 times.

b) Malha Crater seen from the crater rim.
The dark sheet of plateau basalt separates the Nubian Sandstone (white, below) from the pyroclastics (upper part of the crater wall).

c) Aerial view of Malha Crater.
The dark, subrecent lava flow from Jebel Sowidor locally spills over the crater rim and reaches the crater bottom. (The North corresponds to the left side of the photograph).

d) Photomicrograph of the diatomite deposits (plain light).
Magnification about 250 times.

e) Lime sinter crust and diatomite terrace
The children are standing on the highest diatomite terrace (45 meters above the present lake level) with their backs against the corresponding lime sinter crust (dark brown travertine). Note the horizontal Nubian Sandstone layers on the right part of the photograph and the scattered black basalt boulders on the crater slopes.

is covered today by the coarse sandy lake shore sediments.

Apart from these Holocene shore sediments, which will be studied in several other publications, two more deposits finally must be mentioned to complete the petrological description of the Malha crater : the light grayish, soft diatomites and the grayish-brownish, more or less coherent lime-sinter crusts. They are suspended at various levels on the Nubian Sandstone outcrops of the crater wall. The highest sinter formation (or travertine) has been observed at about 45 metres above the present lake surface. It shows many imprints of a well developed reed vegetation, thus indicating an important former fresh water spring level. A close association between sinter and diatomite appears in most cases : the sinter, as a shore deposit, is "growing" on the sandstone outcrops, while the diatomite is developed more away from the wall, as an original lake deposit (fig. 3 d et e). Between both formations one can observe a transitional zone where wedges of sinter are intercalated into the diatomite, and vice versa. As a matter of fact, the associations sinter-diatomite correspond to previous lake shores characterized by a marshy vegetation around bicarbonate-rich water springs. Moreover, the bicarbonate solution shows undirect evidence for the presence of lime in the Nubian Sandstone Complex. In any case, it is obvious that all these phenomena took place under humid climatic conditions. The age of these deposits is probably Late Pleistocene or Early Holocene. Unlike older Pleistocene sinter accumulations from Italy and Haiti, they do not consist of calcite : their mineralogical composition is almost completely aragonitic. This may suggest a rather recent age. On the other hand, it should be stressed that part of these formations already suffer from strong erosion. However, it must be admitted that their present geomorphological position and their friable nature combine to stimulate their physical decay by the rain showers during the short rainy season. These showers are also responsible for the quick development of several deep and steep radial clefts cutting through the pyroclastics of the crater rim by regressive erosion (fig. 4). They are used by men and cattle as access roads to the crater lake.

The geological history of Malha Crater may be summarized as follows :

- Crystallisation of the Precambrian Basement granite (a slow process at great depth, involving high temperatures and high pressures).

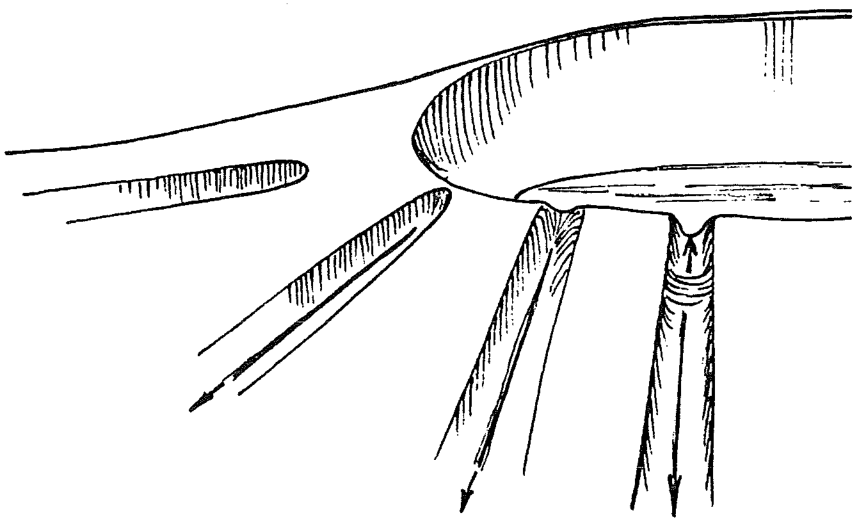

Fig. 4 : Evolution of the radial Clefts by present Erosion
From left to right : successive stages finally resulting in cutting through the pyroclastic crater rim, and in inversion of drainage towards the steep internal slope of the crater. The dimensions and the numbers of the clefts have been exaggerated.

- Erosion of the upper Precambrian layers. Development of an erosion peneplain on the granitic Basement.
- Deposition of the detrital Nubian Sandstone Complex (by wind, rivers or sea, during the Cretaceous ?).
- Formation of paleosols by strong Mid-Tertiary pedogenesis on Nubian Sandstone surface. Deposit of first volcanic ash layers. Evidence of humid conditions. Kaolinization in depth of the Basement under influence of permanent groundwater table.
- Outflow of plateau basalt (Late Tertiary fissure eruption).
- Creation of Malha crater by phreatomagmatic explosion (End Tertiary - Early Pleistocene).
- Inflow of lava tongue from Jebel Sowidor.
- Formation of sinter (travertine) and diatomite at different levels reflecting previous crater lake developments during Late Pleistocene - Early Holocene.
- Deposit of present lake sediments.

No specific data existed on the Malha Crater geology. All information given in this paper has been gathered in the field during the Belgian expedition to Norhern Darfur in the autumn of 1985, directed by Prof. H. DUMONT, and afterwards in the laboratory from the study of the collected samples. However, two books have been particulary useful for a better understanding of the general geological framework of Sudan : TOTHILL (1948) and WHITEMAN (1971).

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