GAS ESCAPE STRUCTURES IN PRECAMBRIAN PERITIDAL CARBONATE ROCKS

W. Hegenberger

ABSTRACT

Sub-vertical tubular structures from the lower Nama Group are described and compared with similar examples from the Damara Sequence of Namibia and from the Noab Formation of the Naukluft Mountains (Hartnady, 1978) and from the Noonday Dolomite of California (Cloud et al. 1974). At all localities the country rocks are light grey, peritidal cryptalgal laminated dolomite. The structures, 0.5 to 2.5 cm in diameter, are circular to oval in cross-section, their length varies between 0.1m and possibly several metres. The pipes were filled either immediately with carbonate mud or small fragments of surrounding laminites, or at a later stage with chert and/or coarse sparite; some even remained open. The tubes are orientated vertically to the palaeohorizon and flatlying lamination or at an angle to the lamination on the flanks of algal buildups. From their common environment it is inferred that the structures are facies-dependent. The shape of the pipes and composition of their fillings, as well as a comparison with modern, intermittently exposed shallow water sediment, suggest that they are gas- and water-escape structures. Gas is formed by the decay of the algal mats during low tide, while water could play a subsidiary role in generating high pressure.

1. INTRODUCTION

Mapping of the late Precambrian Kuibis Subgroup of the Nama Group in the eastern Windhoek and Gobabis Districts of Namibia (Fig. 1) proved an intertidal depositional environment for the Bildah Member of the Buschmannsklippe Formation (SACS 1980; Hegenberger, in prep.). This member consists of light coloured, cryptalgal laminated dolomite, up to 50 m thick, that displays desiccation cracks, algal buildups, stromatolites and indications of locally intensive reworking. Within the Bildah dolomite, many bedding planes are studded with round to oval, 1 to 2.5 cm diameter, depressions and crater-like features, spaced 1 to 5 cm apart (Fig. 2). These features, which are commonly filled with large carbonate crystals (Fig. 3) and, more rarely, chert, are distributed irregularly through the Bildah dolomite but are most abundant in the central Witvlei Synclinorium (area 2218 CA). From natural exposures and large polished slabs (“Witvlei Marble” from Kehoro 183, area 2218 BA) it is obvious that the structures represent sections across tubular features that intersect the laminite (Figs. 4 and 5). Similar structures are known from the Noab Formation of the Naukluft Mountains (Hartnady, 1978) and from the Auros Formation of northern Namibia. These features from Namibia are comparable to structures described from the Noonday Dolomite of California (Cloud et al. 1974).

2. DESCRIPTION

2.1 Eastern Windhoek and Gobabis Districts

The structures are restricted to the dolomitic facies of
the Bildah Member of the Buschmannsklippe Formation (Kuibis Subgroup, lower Nama Group). Vertical sections show that the features on the bedding planes (Fig. 2) are the surface expression of tubular structures (longer than 30 cm) which are sub-perpendicular to the lamination. In longitudinal sections of polished slabs from Kehoro 183, the pipes are 1 to 2.5 cm in diameter, more than 5 cm apart, and deviate by up to 15° from a right angle to the lamination (Figs. 4, 5). Filling consists predominantly of coarse, crystalline carbonate or micrite with subordinate chert and megaquartz (Fig. 3) and tabular carbonate fragments, 0.5 to 1 cm long. The latter are apparently fractured and redeposited laminites that are orientated subhorizontally. Chlorite is a minor constituent of some pipe fillings (Fig. 6).

Most of the laminae pierced by a pipe are inclined toward this structure, thereby furnishing a way-up criterion for identifying the top of unoriented slabs (Figs. 4 to 7). The maximum length measured on material from Kehoro, viz. 30 cm, is not the greatest actual length because the axes of the pipes cut the polished plane at a high angle. The top sections of some tubes, however, widen funnel-like and are overlain by flat-lying laminaion (Fig. 7). This contrasts markedly with most other tubular structures: these “end” conically and the laminae “overlying” them form a depression in continuation of the tube’s axis (Figs. 4 and 5). The funnel-shaped ends are interpreted as the orifices, but still the length of the specific structures remains unknown because the opposite end is not exposed.

Most of the tubes from Kehoro 183 are surrounded by a 1 to 5 mm wide zone of bleached country rock (Figs. 4 to 7); in some cases even the exterior portion of the micritic fill in the tubes has been discoloured. In one sample the bleached zone on both sides of the longitudinal section (3 - 4 mm wide) is fringed by an about 1 mm thick reddish seam which represents the leached and subsequently reprecipitated iron content of the discoloured core.

2.2 Naukluft Mountains

Hartnady (1978) described pipe-like features from a massive, finely layered dolomite of shallow tidal origin...
which belongs to the Noab Formation of the Naukluft Nappe Complex (Fig. 1). The structures are about 10 cm long, with circular cross-sections measuring 1.5 cm; these are filled by quartz, sparry calcite and dolomite. From Fig. 9 in Hartnady’s thesis (1978) it is inferred that both their ends pass into bedding-parallel carbonate veins (sheet cracks?).

2.3 Grootfontein and Outjo Districts

In the uppermost portion of the Auros Formation (Abenab Subgroup, Otavi Group, Damara Sequence) a marker, known to the geologists of the Tsumeb Corporation as “quartz cluster” structures, is found at scattered localities over a distance of 300 km along strike (Fig. 1). The descriptive term “quartz clusters” applies to plug-like siliceous bodies of irregular circular to oval cross-section which rise for 1 to 2 cm above the bedding-parallel surface. They represent portions of vertically disposed quartz fillings of pipes which form resistant studs after the surrounding dolomite has been eroded (Fig. 8). The country rocks are light grey, finely laminated, forming thick layers. On Gauss 40 and Auros 595 in the Otavi Mountains it is clearly visible that many of the subvertical structures developed out of sheet cracks, i.e. cracks formed parallel to algal laminations and caused by decay of the algal matter (Figs. 9 and 10). On Bothashof 476, 85 km west of Outjo, the tubes have a minimum length of 70 cm (Fig. 11) and are filled with chert, quartz and sparry carbonate. In many of them silica forms a thin outer seam while
the centre of the tube is occupied by carbonate crystals or left hollow (Fig. 12). Round structures measure 1 to 2 cm across, but some are compressed to an elliptical cross-section. Distances between them vary from 1 to 5 cm (Figs. 8, 11-13). Where the sparite filling predominates, the structures look identical to those in the Bildah Member, while those with a higher silica content are “quartz clusters” (Fig. 8). The country rock is again light grey, laminated dolomite. Thin chert seams, probably filling of sheet cracks, accentuate lamination and generally form at right steep angle to the pipes (Figs. 11 and 12). A dome-shaped organic buildup, about 8-10 m across, is riddled by tubes irrespective of the dip of the laminae which, at the flanks, is as steep as 60°. There the tubes stand vertical as everywhere else but form an angle of 30° with the laminae (Fig. 13). Throughout the domal structure they are parallel to each other and to those in the flat-lying strata.

2.4 Noonday Dolomite, California

Tubular structures in cryptalgal carbonate have been described in great detail by Cloud et al., (1974) from the Noonday Dolomite of eastern California (Wright et al., 1978). They were observed in large algal mounds where they display the same relation to lamination as those in the Auros Formation on Bothashof; however, they are absent in those portions of the mounds where the inclination of the strata at the flanks exceeds 20°. The maximum length of apparently several metres (Cloud et al., 1974, p. 1880) is much more than is known from the Bildah Member, the Noab Formation and the Auros Formation, but this might partly be a result of better exposure of the Noonday Dolomite.
3. ORIGIN OF THE STRUCTURES

From their appearance in the Bildah Member one can assume that the structures originated as hollow tubes; they were filled either from above by lime mud or from below by fragments of the laminae which were re-worked and expelled by the same forces that produced the pipes, and in places settled out of the transporting medium in a layered manner. Many of the tubes, however, remained open for a while and were diagenetically filled by sparite and/or chert. The stability of the cavities, even if they penetrated a still soft sediment, was ensured by the internal cohesion of the surrounding algal mats. Fragmentation of the laminae indicates that portions of the wall rocks were slightly hardened, probably by previous desiccation, while downward dip of the laminae around the pipe points to a certain plasticity of the sediment, causing sagging into the cavity. This downward dip of many of the laminae around the channels observed in polished sections of the Bildah Member, is not common in the Noonday Dolomite (Cloud et al., 1974, p. 1877) and is also not apparent in the Auros Formation. This may be attributed to greater stability of the sediment as compared with the Bildah Member. The walls of the pipes are irregularly indented, possibly due to differential reaction by the laminated matter of the wall rocks to pressure.

The nature of the filling, which lacks any regular lamination, excludes an interpretation of the tubes as columnar stromatolites, such as they are known from the Bildah Member (Fig. 14). From the regular, straight shape and the parallel orientation, an explanation of the tubular features as animal burrows can be excluded, particularly as no Ediacarian burrowing animals are known which could have produced borings of that size (Glaessner, 1984).

The approximately 700 m.y. old Auros Formation of
decaying organic matter - here algal mats - formed gas, mainly carbon dioxide, methane, ammonia, hydrogen sulphide and hydrogen (Cloud, 1960). In the intertidal environment this happened mainly during desiccation, i.e. at low tide. The gas collected along sheet cracks (resulting from decomposition of algal matter in laminae) and forced its way through the overlying sediment pile when pressure grew strong enough, e.g. when the hydrostatic pressure decreased during lowering of the water level (Cloud, 1960).

Klippel (1939) described a mud-bank in an abandoned river channel which some time after emergence above water level was studded with thousands of small craters (pit and mound structures) caused by repeated gas eruptions. The main conditions to be met were: Slowly moving to stagnant water; deposition of mud enriched in organic material, subsiding water and emergence for days during hot weather leading to decomposition of the organic material. Similar gas craters in muddy sediments in the tidal zone of the Wadden Sea were men-tioned by Häntzschel (1941). Experiments performed by Schäfer (1954), with air pressed into mud from underneath, showed that the sediment cracked when covered with shallow water but formed discrete craters if not under water.

b) Escape of water could have been caused by artesian egression (Cloud et al., 1974) or by expulsion of pore water by compression of the lime mud during continuing sedimentation. But this alone would not explain the reduction seams and precipitation of iron compounds at the walls of the tubes. It could, however, better account for their length than decay of organic material alone can, which is believed to affect mainly the uppermost part of the sediment. A combination of both agents, viz. gas kinetics and hydraulics, is offered by Goemann (1939) who explained gas escaping from sediments in the tidal zone of an estuary as generated by decomposition of organic material during low tide, forced out of the sediment during tidal rise, going together with a rise of the groundwater table within the sediment. The maximum length of the escape channels observed by Goemann (1939) was 1.5 cm; they were surrounded by reduction zones, caused by hydrogen sulphide.

Cloud et al. (1974) discussed the origin of the tubes in the Noonday Dolomite and rejected 1) factors controlled by jointing, 2) metazoan burrows, 3) interpretation as interspaces between columnar stromatolites, 4) columnar stromatolites, 5) solution pipes, 6) root casts. They rather agreed that the structures were formed by syndepositional upward escape of gas and/or water; this is confirmed by the structures studied at SWA/Namibian occurrences.

To sum up, there is strong evidence that gas produced by decaying algal mats played a major role in forming the pipes. But it is uncertain whether this alone was sufficient to generate a pressure strong enough to pierce through nearly one metre or more of sediment, or whether it was promoted by compaction of the lime mud (possibly accelerated by dewatering during low tide), groundwater rising with the tide or other agents.

4. ACKNOWLEDGEMENTS

Prof. H. Martin and Mr. A. Günzel are thanked for stimulating discussions in the field, Drs. K. Schalk and J. Ward for their comments on an earlier draft.

5. REFERENCES

Hartnady, C.J. 1978. The structural geology of the

58

Hegenberger, W. In prep. Stratigraphy and sedimentology of the Kuibis Subgroup (Nama Group) in the Windhoek and Gobabis Districts of Namibia. Mem. geol. Surv. SWA/Namibia.


