

**THE ROTER KAMM METEORITE IMPACT CRATER AND ITS EJECTA APRON IN THE SOUTHERN NAMIB DESERT OF SOUTHWESTERN NAMIBIA.** Roy McG. Miller, Consulting Geologist (PO Box 11222, Windhoek, Namibia, rmmiller@mweb.com.na)

**Introduction:** The almost circular crater [1] is 2.8 km in diameter and is located in an area of vegetated dunes (Fig. 1) punctuated by a few, small, mobile barchan dunes and by shadow dunes on the lee side of the protruding crater rim. The rim is composed entirely of Namaqua gneiss. Its highest point is 140 m above the surrounding plains and 158 m above the deepest point inside the sand-filled crater. Impact glass in an ejecta fragment yielded an  $^{40}\text{Ar}$ - $^{39}\text{Ar}$  plateau age of  $3.7 \pm 0.3$  Ma [2]. Detail on the crater has been provided in subsequent publications [3-9]. The ejecta apron outside the crater is described in this presentation and by Miller [10].

**Pre-impact stratigraphy of the target area:** This was as follows:

*Sossus Sand Formation* (top): Unconsolidated aeolian sands of the present Namib erg; thin but of variable thickness; base about ~4 Ma; still accumulating today. Sporadic outcrops of the underlying stratigraphic units peep through these sands outside the crater;

*Rooilepel Sandstone Formation:* Red-brown, semi-consolidated aeolianites; equivalent to the aeolian Tsondab Sandstone Formation further north; these aeolianites formed an older, more extensive Namib erg dated between 20 and 5 Ma by an evolutionary sequence of egg shells of ostrich-like birds [11];

*Gariiep Supergroup:* Thin, scattered remnants, often only 2 m thick, of a huge thrust sheet of grey to white limestone with occasional brown jasperoid veins; between 750 and 600 Ma in age; tectonically emplaced onto the underlying gneiss at about 545 Ma;

*Namaqua Metamorphic Complex* (base): Upper amphibolite facies granitic gneiss; mainly coarse-grained to porphyroblastic, granodioritic biotite gneiss; lesser amounts of coarse-grained leucogneiss; minor short, thin, post-tectonic granitic pegmatites up to 50 cm thick and a few metres long, some zoned with thin, podiform quartz cores; one pair of parallel, post-tectonic quartz veins up to 50 m long and 4 m thick some 1.5 km southwest of the crater; 1200 Ma.

**Crater rim:** The granodioritic biotite gneiss forms the bulk of the elevated crater rim with the leucogneiss forming the northwestern part. Black and occasionally grey, green or red cataclasite veins (not pseudotachylite) occur in various concentrations around the whole rim. Most have a sub-millimetre thickness but a few are up to 2 cm wide. They occur singly and in clusters and both with and without associated brecciation of the gneiss. A marked radial orientation of the

veins occurs along the northwestern and eastern parts of the rim. Many veins in the southern part of the rim are concentrically orientated but have both inward and outward dips. Small patches of brecciated gneiss in the north and east are blackened and soaked by pervasive cataclasite. Radial fractures in a Gariiep limestone outcrop just southwest of the crater either contain black cataclasite or are bleached to a mustard colour. Fragments up to 2 cm in size of gneiss and cataclasite veins occur suspended in aeolian sand south of the crater. These vein fragments are commonly 2 mm thick, are unlike any of the veins in the southern part of the rim and are believed to have weathered out of the underlying gneissic basement. A feature of the northwestern, northern and eastern rim are *in situ* patches in the gneiss and associated pegmatites that are variously brecciated and contain blackened feldspar.

**Ejecta on the crater rim:** Large, disorientated, metre-sized blocks of granodioritic biotite gneiss cover the inner and outer parts of a small portion of the northern rim. A few such blocks occur on the western rim. Other ejecta fragments resting loose on the rim gneisses include, in decreasing order of abundance, reddish vein quartz breccias (the largest >1 m in size and occurring on the eastern and northwestern parts of the rim), fragments of gneiss and pegmatite with blackened feldspar, carbonaceous and graphitic schist, suevite, grey and mustard-coloured limestone, associated brown jasperoid, and rare pink porphyry-like quartz-feldspar rock, sandstone, and metre-size blocks of unbrecciated milky vein quartz (on the northeastern part of the rim). Unusual is a strewn field covering an area of about 1000 m<sup>2</sup> on the inner part of the northwestern rim of blocks of brecciated milky vein quartz up to 30 cm across cut by black veins of almost pure SiO<sub>2</sub> cataclasite between 1 mm and 10 cm wide containing variable amounts of angular milky quartz fragments. The strewn field includes fragments of the cataclasite that separated from the rest of the quartz breccia as well as a few smooth-surfaced, flädle-like fragments of carbonaceous schist breccia. Fragments of gneiss or pegmatite breccia pervaded by black cataclasite and black cataclasite fragments may be weathered out remnants.

**Ejecta outside the crater:** These are concentrated in an outward-fanning apron north and west of the crater and form a calcretised layer above unconsolidated aeolian sand of the Sossus Sand Formation. A few fragments of brecciated gneiss, black cataclasite and rare suevite, either loose or calcrete cemented, occur on the

outer eastern and southern slopes of the rim. Not a single ejecta fragment was found on the Gariiep limestone just southwest of the crater. In contrast, ejected fragments of gneiss form an almost continuous blanket between 1 km and 2 km northwest of the crater. Fragments >20 cm in size (Fig. 2) occur in both radial and concentric concentrations relative to the crater rim. The longest such radial arm extends for a distance of 5 km in a northwesterly direction from the northwestern crater rim. The largest fragments of 1m to 1.5 m in size form a concentric swath 1.5 km from the crater rim. Short, black, sub-millimetre cataclasite veins are extremely rare in such fragments. Gneiss fragments with blackened feldspars occur in a few patches and milky quartz fragments identical to those in the strewn field occur in the ejecta apron northwest of the strewn field. The contacts of the leucocratic gneiss to the granodioritic biotite gneiss form fixed points in the crater rim that can be traced into the distribution of the fragments in the ejecta apron but splay outwards away from the crater (Fig. 3). The milky quartz fragments show a similar outward splay.

**Projectile trajectory:** The limited number of ejecta fragments east and south of the crater, the large concentration of fragments from the north to the west of the crater, the large size of these fragments, the radial and concentric concentrations of the large fragments, the fanning splays of leucogneiss and milky quartz fragments and a slight northwesterly elongation of the crater of about 110 m suggests that the impact projectile followed a northwesterly trajectory.

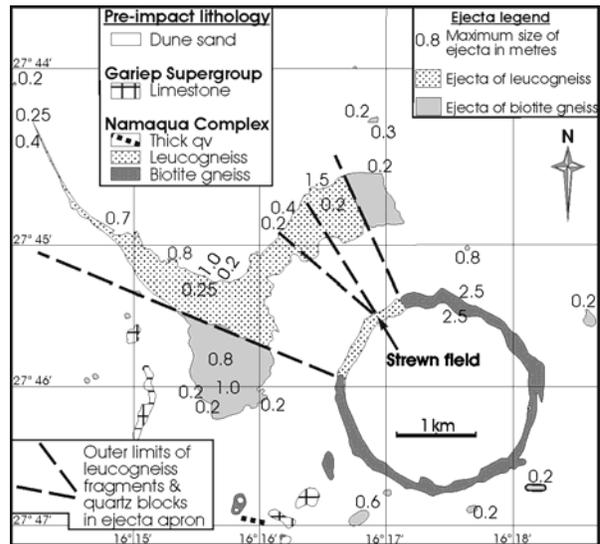
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**Figure 1:** Oblique aerial view of the 2.8 km diameter Roter Kamm Impact Crater; view westwards across the crater.



**Figure 2:** Large ejecta blocks of leucogneiss up to 1.5 m in diameter almost 2 km northwest of the crater; at number 1.5 in Figure 3. Crater rim in background.



**Figure 3:** Highly simplified map of the crater showing the ejecta apron to the north and west of the crater and the way in which specific ejecta types fan outwards away from the crater towards the northwest.