SEARCH FOR IMPACT CRATERS IN ETHIOPIA: NO METEORITE IMPACT STRUCTURE AT SHAKISO

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Abstract. Currently, 18 impact structures have been identified on the continent of Africa. No impact structures are so far known in Ethiopia, with the exception of a suggestion of an impact crater centered on the town of Shakiso, southern Ethiopia. Our field work, petrographic, and geochemical studies on rocks from the area do not show any evidence of an impact structure at that locality.

1. Introduction

Over the last 15 years, renewed interest in the events that led to the extinction of the majority of all life on earth at the end of the Cretaceous period, 65 Ma ago, implicated a large-scale asteroid or comet impact as the cause of this catastrophe. It is now well established that impact cratering is one of the most important surface-altering processes on terrestrial planets and planetary satellites. Detailed studies, mainly since the 1960s, have led to the recognition of about 150 impact structures on earth. Currently, about 2–5 new impact craters are being described every year. In 1994, only 15 confirmed impact structures were known in Africa (Koeberl, 1994). For a long time, the discovery rate of impact craters in Africa lagged behind that of most of the rest of the world. Dietz (1965) listed 8 structures as probable young impact craters, all of which are now confirmed. Four of those were in Africa. The situation remained unchanged, until in the mid 1970s several U.S. and French expeditions to the Sahara regions identified several mostly small impact structures in Mauritania, Algeria, and Libya (see Koeberl, 1994, for details). Then nothing changed until, during the last few years, another attempt was made to improve the African record, this time in southern Africa.

The currently known impact craters in Africa are listed in Table I. Considering the substantial importance of impact craters for geology in general, but also for a possible economic interest, impact craters deserve more extensive study. It should be noted, though, that it is necessary to use unambiguous criteria for the identification of impact structures. The formation conditions of impact craters lead to pressure and temperature conditions in the target rocks that are significantly different from those reached during any internal terrestrial processes. Among the most characteristic changes induced by the impact-generated shock waves are irre-

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TABLE I
The Known African Meteorite Impact Craters

Name	Country	Latitude	Longitude	Diameter	Age (Ma)
Amguid	Algeria	26°05′ N	04°23′ E	0.45	≤0.1
Aorounga	Chad	19°06′ N	19°15′ E	12.6	>0.01
Aouelloul	Mauritania	20°15′ N	12°41′ W	0.36	3.1 ± 0.3
B.P. Structure	Libya	25°19′ N	24°20′ E	2.8	<120
Bosumtwi	Ghana	06°32′ N	01°25′ W	10.5	1.1 ± 0.2
Gweni-Fada	Chad	17°25′ N	21°45′ E	14	<300
Highbury	Zimbabwe	17°05′ S	30°09′ E	20	1000–1800
Kalkkop	South Africa	32°43′ S	24°26′ E	0.64	<5
Morokweng	South Africa	26°31′ S	23°32′ E	200	145 ± 2
Oasis	Libya	24°35′ N	24°24′ E	11.5	<120
Ouarkziz	Algeria	29°00′ N	07°33′ W	3.5	<70
Pretoria Saltpan	South Africa	25°24′ S	28°05′ E	1.13	0.2
Roter Kamm	Namibia	27°46′ S	16°18′ E	2.5	3.7 ± 0.3
Sinamwenda	Zimbabwe	17°12′ S	27°47′ E	0.22	<10
Talemzane	Algeria	33°19′ N	04°02′ E	1.75	<3
Tenoumer	Mauritania	22°55′ N	10°24′ W	1.9	2.5 ± 0.5
Tin Bider	Algeria	27°36′ N	05°07′ E	6	<70
Vredefort	South Africa	27°00′ S	27°30′ E	180–300	2024 ± 5

versible changes in the crystal structure of rock-forming minerals, such as quartz and feldspar. These shock metamorphic effects are characteristic of impact and do not occur in natural materials formed by any other process. It is with such mineralogical evidence, together with several independent chemical, isotopic, dating, and geophysical studies, that impact structures are confirmed (see reviews by Grieve, 1987, and Koeberl, 1994).

Since the publication of the review by Koeberl (1994), three new African impact structures have been identified: the small 220 m diameter Sinamwenda crater in Zimbabwe (Master et al., 1996), the 14 km diameter Gweni-Fada complex crater in Chad (Vincent and Beauvilain, 1996), and the large (about 200 km diameter) Morokweng impact structure in South Africa, near the border with Botswana (Koeberl et al., 1997). Considering the size of the African continent and compared to the density of impact craters elsewhere in the world, 18 craters is a small number. However, today Africa is still far from its share of known established impact craters compared to those known elsewhere in the world. Cratering rate estimates (e.g., Grieve, 1987) indicate that numerous, so far undiscovered, craters must exist in Africa.

No impact structures are so far known in Ethiopia. Ethiopia is one of the larger countries in Africa, with an area of about 1.13 million km^3 (slightly less than twice the size of Texas). Topographically, the country comprises about 50% of highland areas, divided by the Rift Valley, with some low-lying desert areas near Djibuti and Somalia. Due to political instability, relatively little international geological studies were done in Ethiopia over the past decades. In January and February 1996, we performed field studies in Ethiopia in an attempt to identify possible impact structures. In addition, satellite images of selected areas were studied as well. Field work was done in north central Ethiopia (in the area around Lake Tana), and in south central Ethiopia (around Shakiso, Sidamo province).

Lake Tana is the largest lake in Ethiopia and the source of the Blue Nile. It has an average diameter of about 60–70 km, but is very shallow, with an average depth of only 9 m. Lake Tana occupies the center of a large circular basin of at least 100–120 km in diameter, which is apparent on topographical maps. The area is covered with Quaternary alkaline olivine basalts (Merla, 1973), which may have a thickness of up to 1300 m (Mohr, 1971). Around Lake Tana, pumice and scoria are found at several locations. The origin of Lake Tana has been ascribed to rifting (Lake Tana Rift; Kazmin, 1972), but this hypothesis is largely untested. We collected a number of rocks from outcrops around Lake Tana and from Daq Island in the south-central part of the lake for petrographical and geochemical studies. Our data (Abate et al., 1998) confirm that the rocks are young basalts. Several drill cores, which were drilled to a depth of <100 m for water resource reasons, were studied as well, but none of the cores reached basement. While it is clear that the Lake Tana area is presently covered by several basalt flows, the basin could be more than just a geologically recent structure. However, presently available data do not allow any conclusions regarding an impact origin of this basin, and no indication of an impact association was derived (Abate et al., 1998).

Evdokimov (1987) and Evdokimov and Abebe (1987) reported on the presence of a possible impact structure at Shakiso (centered at 5°46′ N and 38°54′ E), south-central Ethiopia, about 500 km from Addis Ababa (Figure 2). Shakiso is situated in the fairly well-studied Adola gold field. Rocks outcropping in the area belong to the about 630–680 Ma old Middle Complex in the classification of basement rocks of Ethiopia (e.g., Kazmin, 1972; Chater 1971). These rocks include N–S trending biotite gneiss and muscovite-kyanite schists forming the gneissic terrain that surrounds the Adola greenstone belt (e.g., Gebreab et al., 1992).

Evdokimov (1987) reported on the existence of “impactites and explosion breccias” as well as Ni-Fe pellets. Geological data supposedly indicate a structure with about 2.5 km diameter centered directly on the town of Shakiso, extending about half way to the Hawata river (Figure 2). He cited an age of about 10 Ma, but without giving any analytical data to support this age. Evdokimov and Abebe (1987) revised the diameter to 6 km based on the occurrence of “shatter cones” and gave an age of 65 Ma.

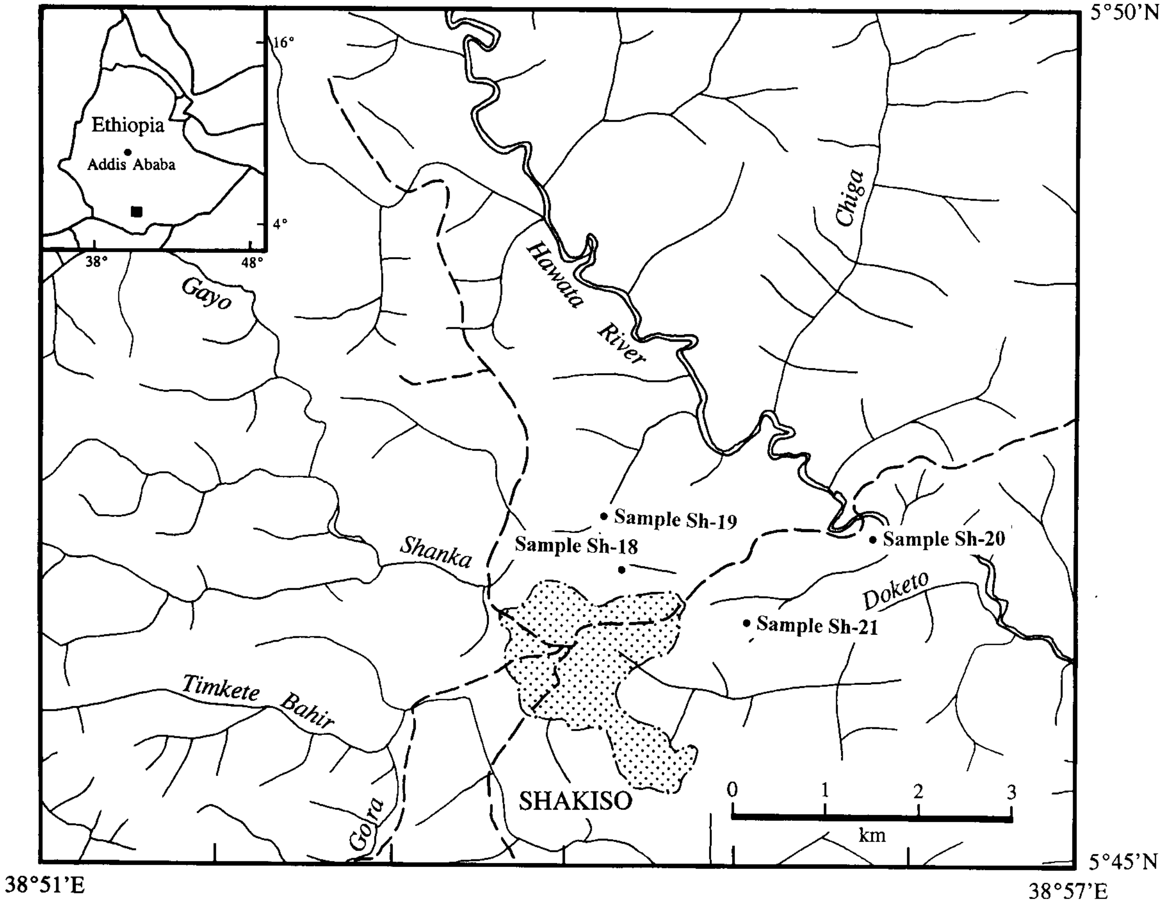

Figure 1. Map of Shakiso Area. The town of Shakiso is shown as the dotted area, roads are indicated by dashed lines, and thin solid lines mark rivers and creeks. Sample locations are marked as well.

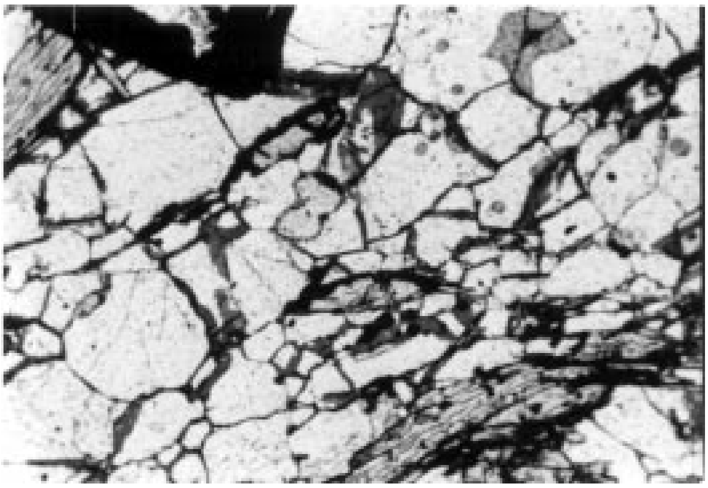

Figure 2a. Photomicrographs of typical rocks from Shakiso. (a) biotite gneiss/muscovite-kyanite schist (Sh-18); at the center mainly quartz grains with iron oxide staining; kyanite grains defining the schistosity of top left and lower right. Crossed polars, field of view is 2.5 mm across. (b) muscovite-kyanite schist (Sh-21), showing well-deformed syn-deformational kyanite crystals (lower right); quartz grains show undulatory extinctions. Crossed polarizers, 2.5 mm long dimension. (c) quartz from a biotite gneiss (Sh-18) with irregular fractures and no indication of shock deformation. Crossed polarizers, 2.5 mm long dimension.

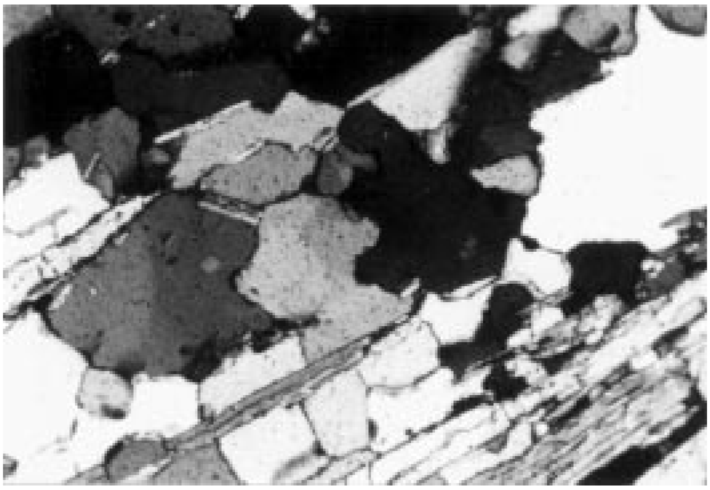

Figure 2b.

In January and February 1996 we visited the outcrops mentioned by Evdokimov (1987) and Evdokimov and Abebe (1987) (cf. Abate and Koeberl, 1996). None of the geological features ("shatter cones", "impact breccias"), described by Evdokimov and Abebe, could be recognized in the field. From our field observations we conclude that slickensides seem to have been mistaken for shatter cones. No

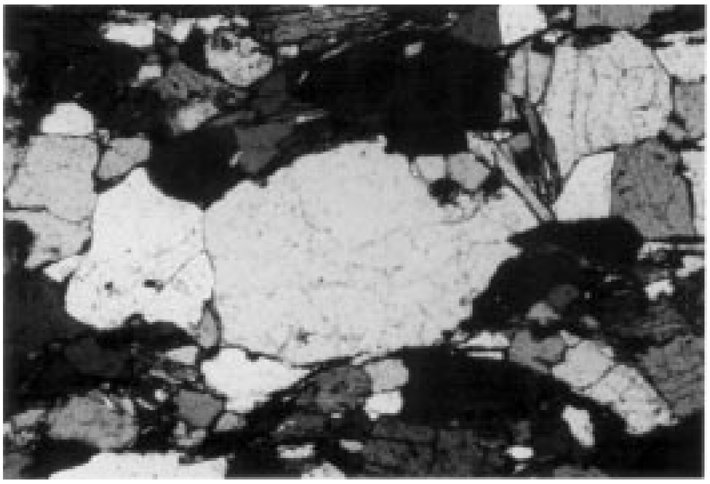

Figure 2c.

significant brecciation was found in any of the about half dozen outcrops that were visited. Quartz veins are common. For more detailed petrographic and geochemical studies (e.g., the search for microscopic shock effects, or an impact-characteristic geochemical anomaly), a set of about 10 representative samples were taken.

In thin section we identified biotite gneiss (composed of quartz, plagioclase, orthoclase, muscovite, biotite, and opaque phases), and muscovite-kyanite schist (composed of quartz, kyanite, sillimanite, muscovite and opaque phases). Figure 2 shows some typical thin section microphotographs. Irregular (non-planar) fractures in quartz and undulose extinction are common in all important rock forming silicates. Fluid inclusions are rare and do not occur in planar trails either. In none of our thin sections we found any indication of shock-characteristic planar deformation features (PDFs) (cf. Stöffler and Langenhorst, 1994; Huffman and Reimold, 1996). Major and trace element contents were measured in four samples (biotite granites/schist: Sh-18, 19, and 21; quartzite: Sh-20) to geochemically characterize the samples. Standard analytical methods (XRF, AAS, DCP-AES, and INAA) were used (Table II). The rare earth element (REE) patterns and abundances (Figure 3) are very similar to those of average upper crustal rocks (Taylor and McLennan, 1985). We also checked if anomalous contents of Ni, Co, Ir, and other possibly impact-derived elements might be present, but the data given in Table II indicate no anomalous enrichment of these elements. We suspect that the “Fe-Ni pellets” of Evdokimov (1987) are actually surficial Fe-Mn coatings (varnish).

In summary, we conducted field work and petrographic and geochemical studies to check the suggestion by Evdokimov (1987) and Evdokimov and Abebe (1987) regarding the presence of an impact structure at Shakiso, Ethiopia. None of the evidence claimed by these authors was found. We suspect that slickensides were misidentified as shatter cones. Microscopic studies do not indicate the presence of

TABLE II

Composition of rocks from Shakiso Area (Southern Ethiopia)

	Biotite Granite	Quartzite
SiO_2	75.93	98.04
TiO_2	0.35	0.02
Al_2O_3	16.39	0.01
Fe_2O_3	2.77	0.91
MnO	0.01	0.01
MgO	0.01	0.01
CaO	0.28	0.03
Na_2O	2.06	0.01
K_2O	0.89	0.10
P_2O_5	0.06	0.04
LOI	0.85	0.10
Total	99.59	99.29
Cr	9.1	5.89
Co	0.91	0.49
Ni	8	20
La	33.4	1.39
Ce	64	2.42
Nd	24	2.16
Sm	3.15	0.62
Eu	0.54	0.19
Gd	3.9	1.3
Tb	0.74	0.24
Tm	0.41	0.063
Yb	2.11	0.25
Lu	0.32	0.024
Ir	<1	<1
Au	0.7	0.6
La_N/Yb_N	13.5	3.75
Eu/Eu^*	0.41	0.64

All Fe as Fe_2O_3, major elements in wt%, Ir and Au in ppb, and all other trace elements in ppm. Biotite granite values are averaged data from three different rocks.

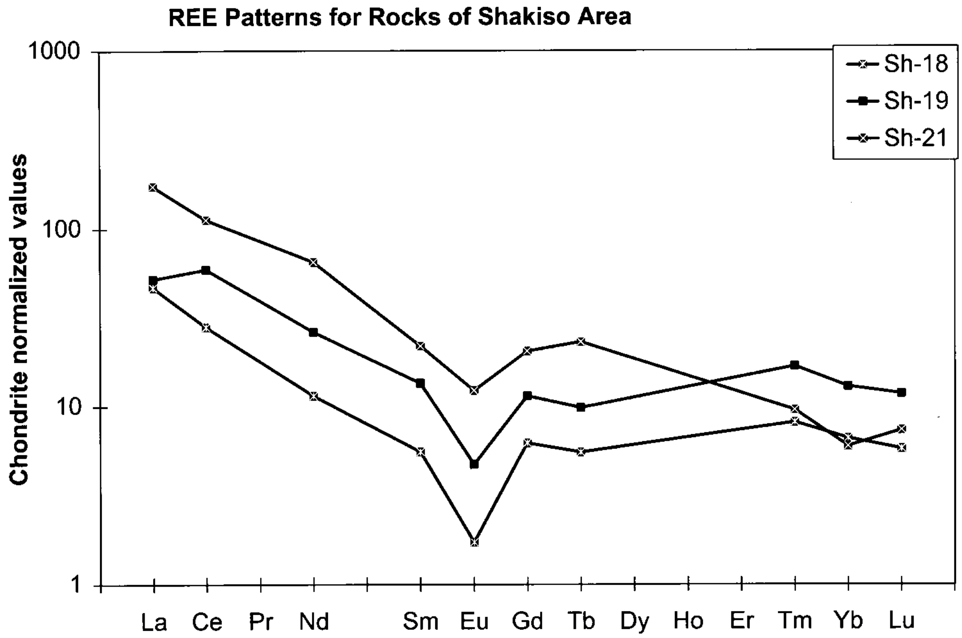

Figure 3. Abundances of rare earth elements (REE) for the rocks of Shakiso area analyzed in this normalized to abundances of Cl chondrites (Taylor and McLennan, 1985).

microscopic shock effects, and no geochemical anomalies are present in the rocks either.

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