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Geology, geomorphology, geodiversity and geoconservation of the Sof Omar Cave System, Southeastern Ethiopia

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ABSTRACT

The Sof Omar Cave System, a spectacular and extensive cave system in Southeastern Ethiopia represents a maze of dry cave passages, which subsequently were crossed by a subterranean watercourse formed by the Weib River, forming combined underground passages of a total length of 15.1 km, the longest and most extensive in Ethiopia. The Sof Omar cave and subterranean river system developed on Jurassic limestone beds particularly on the Gebredarie Series (massive, crystalline limestone beds intercalated with thin marl and mudstone beds). The cave system and the subterranean River developed along a generally horizontal outline within a 20 m thick layer. The Sof Omar gorge is a wide but shallow doline, whose central section is incised by the ancient surface route of the Weib River. Prominent half dolines opening toward the sink and resurgence areas, as well as consistently inward dipping limestone beds at these localities imply collapse phenomenon. Karstification triggered by rift-related uplifting and extension during the mid-Miocene East African rifting, accompanied by extensive collapse along bedding planes likely initiated the caving process. The rifted and collapsed chambers were later widened by slow but persistent dissolution. The dry cave passages were formed earlier than the subterranean river course, though the latter might have partly followed the pre-existing cave passages and enlarged them to form the current subterranean river course. The Sof Omar caves are still at the heart of the cultural and religious life of the local population, where the dry cave passages, domes, and chambers are considered as important religious and cultural locales. With its subterranean river, large chambers connected by narrow and long rift passages, a unique and prominent sinkhole above the caves, wooded gorge teeming with numerous and unique tropical plant and bird species, the Sof Omar Cave System and adjoining gorge has outstanding scenic values. Apart from these naturally outstanding values, what makes the Sof Omar Cave System unique and unsurpassed in the world is its cultural significance. The caves form part of the cultural and religious life of the local population leading to the unique harmony between nature and culture. The cave system and its adjoining forested gorge is a natural–cultural heritage site that requires an active geoconservation.

1. Introduction

There are over 100,000 square kilometers of carbonate rocks exposed in Ethiopia (Fig. 1) but very little is known about the extent of karst terrain. The total length of mapped limestone caves is less than 40 km giving what must be one of the lowest ratios of cave passage/limestone outcrop of any large country in the world (Gunn et al., 2009). Extensive limestone beds are exposed in three regions in Ethiopia: the Mekelle Outlier in the North (Tigray), the Blue Nile Basin in central Ethiopia, and the Ogaden Basin (including the Bale and Western Harrarghe areas where the longest cave in Ethiopia, Sof Omar, and the Mechara karst systems are located, respectively, Fig. 1).

In Southeastern Ethiopia, a massive limestone terrain led to the development of a karst system on Jurassic limestone beds, regionally known as the Antalo Limestone Unit (Bosellini et al., 1997; Asrat, 2002), and locally subdivided into the Hammanlei Formation, Uarandab series and Gabredare series (Assefa, 1988; Bosellini et al., 1997). All the caves in the karst system have been developed on the Gabredare series. The limestone unit, with a total thickness of 500–800 m, consists of thin, fossiliferous limestone beds intercalated with marl and sandy limestone beds at the top (upper Gebredare series), and massive, crystalline limestone beds intercalated with thin marl and mudstone beds at the bottom (lower Gabredare series). The Antalo Limestone unit is

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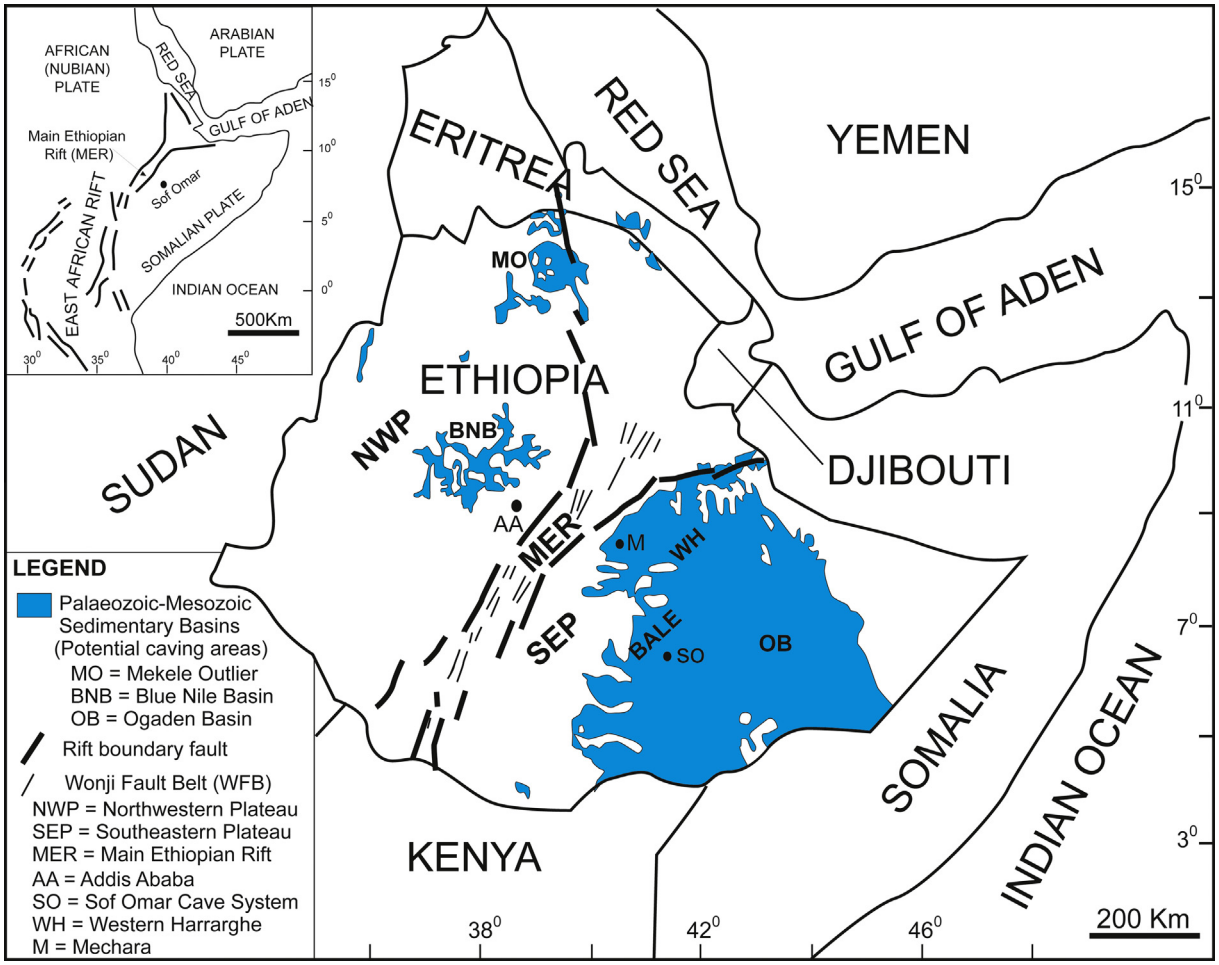

Fig. 1. Regional geological and structural setting of Ethiopia showing major sedimentary terrains. Inset shows the regional structural setting of Northeast Africa.

conformably overlain by Jurassic shale (Agula Shale) with an estimated thickness of 150 m, which comprises variegated shale, marl and mudstone intercalated with thin beds of crystalline limestone and, rarely, dolomite. Cretaceous sandstone (Ambaradam Formation) conformably overlies the Agula Shale. The Ambaradam Formation, with a total thickness of more than 300 m in the karst terrain, consists of white to pink, medium to coarse-grained, immature, clastic sandstone beds intercalated with silt, shale, mudstone, laterite beds and quartz conglomerates. The Ambaradam Formation is exposed in isolated hills/ridges, which form the higher reaches of the undulating plateau.

Both the Tertiary basalts and the Mesozoic succession are affected by fractures and normal faults with general NE–SW orientation parallel to the rift margin. These fractures are thought to be related to the major rifting episode that formed the great East African Rift system as their magnitude and frequency decrease in the southeast direction away from the rift margin. Most of the cave systems in the region developed along major NE–SW aligned rift passages, parallel to the general orientation of the Main Ethiopian Rift, suggesting karstification triggered by rift-related extensional tectonics (Asrat et al., 2008).

The limestone terrain in Southeastern Ethiopia, which extends from the foot of the Tertiary basalt ridge of Western Harrarghe to the Somalia border in the east and southeast has the greatest caving potential. Limestone outcrops in this area are up to 800 m thick locally (the sequence includes numerous intercalated marl and mudstone layers), indicating a great potential for extensive karstification. On the other hand, the limestone outcrops in the north (Tigrai) and central Ethiopia (Blue Nile gorge) are less promising caving areas as the limestone beds are thin and intercalated with extensive beds of shale, mudstone and marl (Asrat et al., 2008 and references therein).

In this contribution, a thorough description and analysis of the geological, geomorphological and cultural settings of the Sof Omar Cave System is given. The main objective of this contribution is to document and analyze this geological and geomorphological heritage of paramount importance, which is crucial for the understanding of an important period of Earth's history. The caves are also significant archives of archaeological, palaeoenvironmental and palaeoclimatic histories (Asrat et al., 2008; Assefa et al., 2014). Furthermore, these geoheritages in general and some selected geosites in particular have to be conserved for their geoheritage significance, hence their thorough recording and description is necessary, as conducted in this work.

2. Methods

This contribution is based on numerous field expeditions to the Sof Omar and many other cave systems in the country since 2003. Detailed geological and geomorphological mapping of the Sof Omar cave area has been conducted in order to characterize the geo logic–geomorphological processes responsible for the karstification of the area. The Sof Omar Cave System and the sub-terranean river system have been thoroughly investigated with the objective of exploring and surveying previously unknown chambers, and documenting all geomorphological, geological and cultural elements of