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STRUCTURE AND GENESIS
Karstification Along an Active Fault Zone in Cyprus

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Abstract

Karstification is occurring along the trace of an active, left-lateral, strike-slip fault zone at Pergamos, Cyprus due to increased permeability from brecciation, fracturing, and steeply dipping bedding in a carbonate/evaporite sequence. The fault zone consists of a restraining bend segment, which strikes east-west and dips steeply to the south, and two strike-slip segments, both of which strike N30˚E and are vertical. Dissolution of subsurface gypsum along all three segments has developed linear trends of sinkholes; no other sinkholes occur in the area. A scarp produced by the fault zone has influenced surface drainage and focused ephemeral stream flow into the sinkholes, further enhancing karstification.

INTRODUCTION

Pergamos is a centuries old, small village in eastern Cyprus (Fig. 1). Present residents report that sinkholes have always existed on the outskirts of the village, and during periods of heavy rain, ephemeral streams will flow into some of the sinkholes, often resulting in additional collapse. Within the past few years, newly formed sinkholes have threatened recent housing developments from the expanding village. Field investigations have determined that the collapses are controlled by a fault system, which cuts through a carbonate/evaporite stratigraphic sequence.

STRATIGRAPHY AND TOPOGRAPHY

Pergamos lies within the circum-Troodos geologic terrane of Cyprus (Fig. 1), comprised of a Cenozoic sedimentary sequence dominated by carbonates (chalks, marls, and calcarenites) and lesser evaporites (Geological Survey Department of Cyprus, 1995). At Pergamos, the near surface stratigraphy (Fig. 2) is flat lying and consists of approximately 4 m of well-indurated calcarenite (Quaternary Athalassa Formation), which overlies approximately 30 m of poorly indurated marl (Pliocene Nicosia Marl), which overlies more than 60 m of massive gypsum (Messinian Kalavasos Formation). Chalks of the Miocene Pakhna Formation underlie the Kalavasos Formation at an unknown depth.

Calcrete is extensive at the surface throughout the Pergamos area and forms a hard, impermeable, indurated mass of carbonate as much as 1.0 m thick and containing laminae greater than 1cm thick. This calcrete is interpreted as correlative to the stage V classification of pedogenic calcrete of Machette (1985). Alluvium, up to a few meters thick, occurs in streambeds, which are incised a few meters into a very flat landscape, which is capped by calcrete.

PERGAMOS FAULT SYSTEM

The Pergamos fault system is a left-lateral, strike-slip system, which consists of two, near vertical, right-stepping segments that strike N30˚E and are connected by an east-west-striking restraining bend (Fig. 3). A south-dipping thrust fault and related fault-propagation fold characterize the restraining bend (Fig. 4). Brecciation and fracturing are intense along the fault system. Bedding in the restraining bend has been rotated to near vertical from the folding and thrusting (Fig. 4). A topographic scarp, from 1-4 m high and down to the north and northwest, occurs along the fault trace.

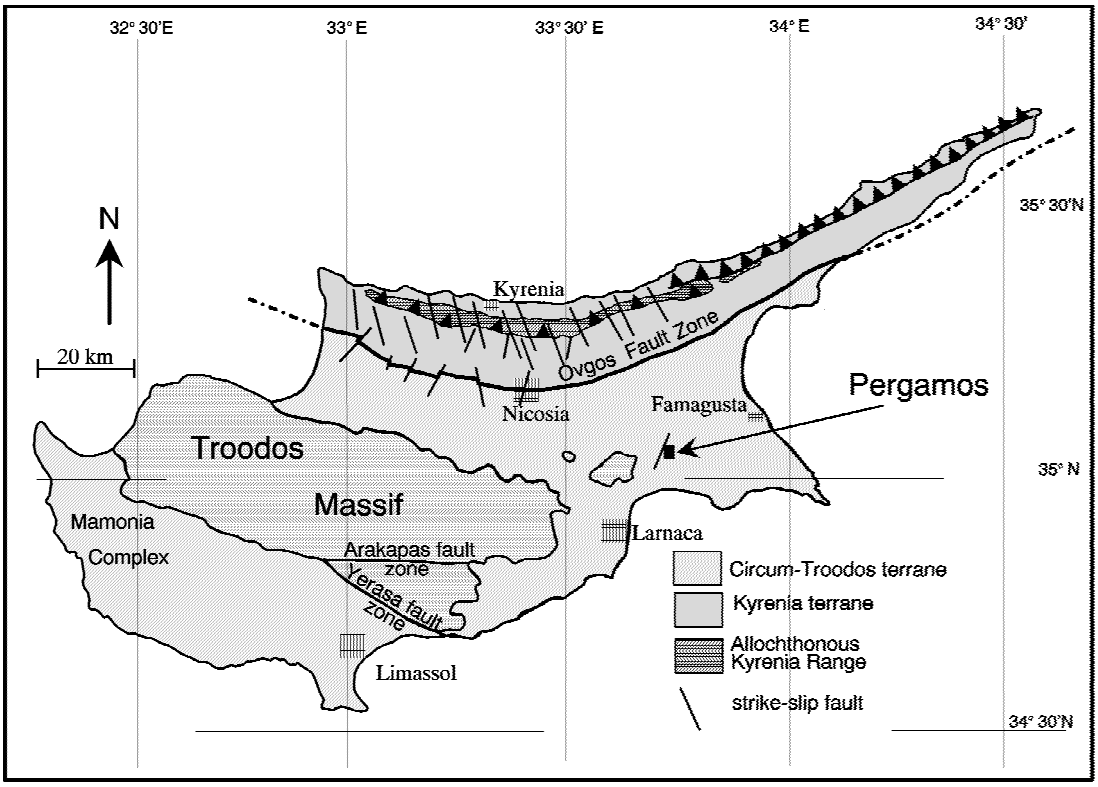

Figure 1. Map showing location of Pergamos, Cyprus.

Figure 2. Generalized stratigraphic column for the Pergamos, Cyprus area, based on logs of drilled wells and a hand dug well that penetrated gypsum. Not to scale; see text for approximate thicknesses.

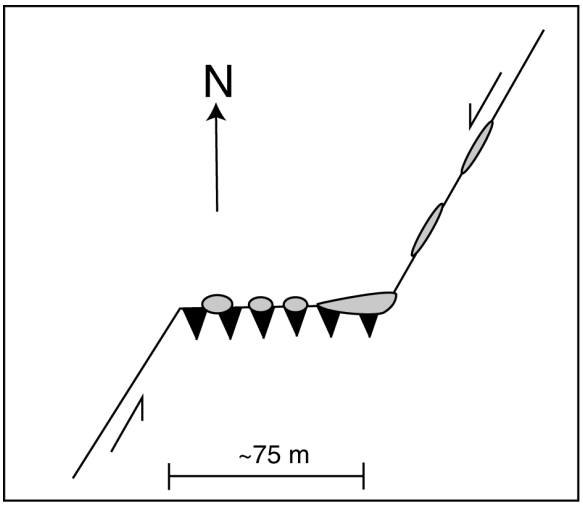

Figure 3. Schematic map of Pergamos fault system. Half arrows indicate relative strike-slip motion; teeth are on hanging wall of east-west-striking thrust fault and related fault propagation fold in restraining bend of fault system. Gray areas are approximate locations and configurations of sinkholes. Photograph in Figure 4 is of the sinkhole furthest to the west.

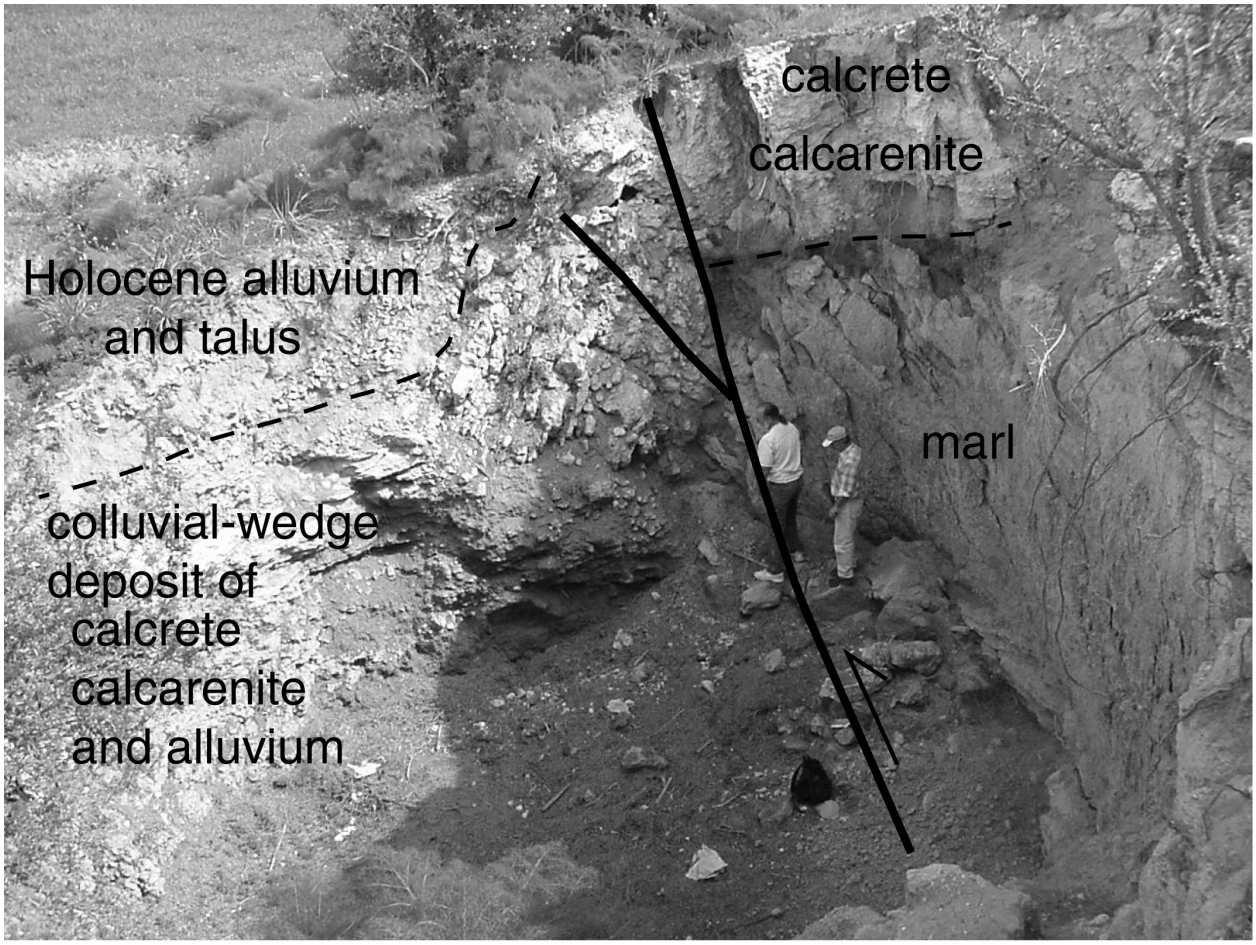

Figure 4. View looking east at sinkhole that developed along the thrust and fault-propagation fold in the restraining bend of the Pergamos fault system. The solid black line marks the approximate location of the thrust; half arrow indicates relative motion.

Deposits in the footwall of the restraining bend consist of deformed bedrock, a Holocene colluvial-wedge derived from the calcrete cap, and Holocene alluvium. Involvement of Holocene alluvium and colluvium in the deformation indicates the active nature of the structure. Also, there is present-day microseismicity along a north-northeast trend in the vicinity of the Pergamos fault system (Makris and others, 2000).

KARST

Sinkholes have developed along the surface trace of the Pergamos fault system (Figs. 3 and 4). These funnel-shaped collapse structures are elliptical in plan view and 10-30 m in elongated dimension. Along the restraining bend they are typically 5-10 m in short dimension; observable depths are as much as 10 m. The southern strike-slip segment is currently inaccessible, however, along the northern strike-slip segment of the fault system, sinkholes occur as very elongated fissures, which are commonly en echelon, and are open to an unknown depth. Between the open fissures, much of the ground has a hollow sound when traversed and feels spongy. Aside from the sinkholes along the fault zone, there are no other known occurrences in the Pergamos area.

Because of the extensive calcrete encrustation, much of the surface water runoff during rainstorms flows into the sinkholes. In addition, ephemeral streams in the area tend to flow into the sinkholes, prompting the

construction of protective berms to keep water out of the sinkholes.

CONCLUSIONS

From our field investigations, it is concluded that brecciation, fracturing, and steeply dipping bedding produced by recent movement on the Pergamos fault system has lead to a localized increased bedrock permeability in a hydrogeologic setting where much of the surface in relatively impermeable because of calcrete encrustation. Surface waters have thus been focused into subterranean flow along the fault system, resulting in dissolution of gypsum and carbonate at depth, and subsequent surface collapse. Outside of the area of increased permeability, there appears to be little or no evidence of karstification.

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