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**COASTAL SPELEOGENESIS AND COLLAPSING BY
EMPTYING OF KARST BRECCIA-PIPES ON THE MARINE
CLIFFS OF THE GARGANO PENINSULA (APULIA, ITALY)**

**OBALNA SPELEOGENEZA IN UDIRANJE ZARADI
PRAZNJENJA KRAŠKIH BREČASTIH CEVI V OBALNIH
STENAH POLOTOKA GARGANO (PUGLIA, ITALIJA)**

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Izvleček

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Ugo Sauro: Obalna speleogeneza in udiranje zaradi praznjenja kraških brečastih cevi v obalnih stenah polotoka Gargano (Puglia, Italija)

Razvoj nekaterih jam v obalnih stenah polotoka Gargano je odvisen od prisotnosti kraških brečastih cevi. Če te cevi, ki lahko predstavljajo tudi vodonosnike, prerežejo obalne stene, jih lahko izpraznijo udarni valovi. Na ta način se lahko razvijajo kupolaste jame, ki se včasih odpro na površje. Prispevek predstavlja model geološke in geomorfološke zgodovine, s pomočjo katerega je mogoče razložiti nastanek brečastih cevi in omenjenih jam.

Ključne besede: obalna jama, kraška brečasta cev, zgornjemiocenska speleogeneza, Gargano, Puglia, Italija.

Abstract

UDC: 551.435.8(450.75)

Ugo Sauro: Coastal speleogenesis and collapsing by emptying of karst breccia-pipes on the marine cliffs of the Gargano peninsula (Apulia, Italy)

In the coastal cliff of the Gargano peninsula the development of some coastal caves is controlled by the presence of breccia-pipes structures. The breccia-pipes, which may host aquifers, when intersected by the cliff are partially emptied by the waves. In this way dome-like caves may develop, which sometimes open to the surface above. A preliminary model of the geological and geomorphological history leading to the formation of the breccia-pipes and of this type of cave is outlined.

Key words: coastal caves, karst breccia-pipes, late Miocene speleogenesis, Gargano, Apulia, Italy.

The coast of the Gargano peninsula is a typical “submerged mountainous coast” of “ria shoreline” type consisting of an alternation of promontories and beaches corresponding respectively to ridges and deep valleys, which dissect the peripheral scarps of the Gargano plateau.

In the headland of the peninsula there is a nearly continuous marine cliff, between 50 and 100 m high. In this sector of the coast there are many sea caves, well known to tourists, because one of the most advertised boat trip is to the cliffs and the sea caves. During the summer period, tens of boats follow the coast each day and enter into many caves. Most caves end with a large chamber occupied by a small circular lake, encircled by a narrow beach.

Although these caves are well known to tourists, they are nearly ignored by the spleo-divers because they end in a few tens of metres and no submerged galleries are known.

So in the volume about the marine caves of Italy (Alvisi et alii, 1994) no mention of the coastal caves of Gargano is made.

THE GEOLOGICAL FRAMEWORK

For a better understanding of the evolution of the coastal cliff and of its caves it is necessary to consider the geological framework of the edge of the Gargano peninsula.

The eastern part of the Gargano consists in a homoclinal sequence of carbonatic formations, sedimented between Cretaceous and Paleogene in transitional environments between a carbonate platform placed to the west and a basin located to the east (Ricchetti & Pieri eds, 1999).

In the context of the tectonic structure of Southern Italy the Gargano is part of the Apulian outer platform, which is the foreland of the Apennine chain, now buckling as a consequence of the eastward migration of the Apenninic margin (Doglioni & Flores, 1997). In particular the Gargano is a kind of complex horst type morphostructure, crossed by different systems of faults, mainly normal, subdividing it in many blocks.

The cliff of the headland of the peninsula is cut in calcarenites rich in chert nodules and lenses, deposited during the Cretaceous in a basin environment, similar in some aspects to the Biancone of Venetian Fore-Alps and to the Craie (“Chalk” in England) of the Paris and London basin. The dip of the beds is to the NE and results partly by the original “clinostatification” and partly by recent tectonic evolution.

On the base of the regional geology, below these calcarenites the following formations should lie: a) bioclastic and detritic limestones (?), b) calcilutites and calcarenites of slope and/or platform environment. Between the latter and the formations above, erosional discontinuities may exist, partly fossilized by lateritic crusts.

SOME ASPECTS OF THE CLIFFS OF GARGANO

Two fundamental contributions have been published about the coastline of Gargano (Kelletat, 1974; Zezza, 1981). The paper of Kelletat is mainly focused on the morphodynamic evolution of the different coastal environments of Gargano; the paper of Zezza deals with the cliffs in calcarenites, the instability phenomena, the typology of landslides, the marine caves as expression of undermining and instability, and the natural risks. Zezza observes that in correspondence with some caves

there are “tectonic breccias”, which increase the risk of collapse. He also remarks how the water circulation inside the most porous structures may increase the instability.

The marine cliff is the result of marine erosion by undercutting of the scarps and favouring rockfalls on the abrasion platform. The sea is able to remove the scree material. The removal is easy also because of the modest size of the fragments.

In general, the undercutting of the cliff is, rather than the effect of mechanical erosion of the waves, the result of solution notch development, that may be considered a form of bio-erosion (Sauro, 1978). On the cliffs of Gargano the solution notch may be also 2 meters deep, and outside of it the inner part of the platform is between some decimeters and some metres deep. The removal of landslide material helps the abrasion of the platform.

THE MARINE CAVES

On the Gargano coast there is a large number of marine caves. Some of these are the result of the dissection of karst caves like tubes and galleries, others present peculiar characters, that are not easily explainable on the base of simple speleogenetic processes. In fact these develop in correspondence with or near to breccia structures, which may be not of tectonic origin. These breccia structures are chimney- or pipe-like bodies showing a vertical development. Not all the breccia - pipes cut by the coastal cliffs have their caves at the base. Some are with no apparent cave.

The cross section of most of the marine caves is controlled by the presence of fracture plains. So according with the setting of these planes, caves with triangular, rectangular and polygonal cross sections are distinguishable (Zezza, 1981). In many caves a dome-like chamber, often of a bell-like shape is present. Kelletat (1974) illustrates the Grotta Sfondata with a sketch of its cross section, and describes its breccia filling as a cork like structure originated by the obstruction with detritic material and now partially emptied by wave erosion. He also recognizes that this type of cave is a peculiar one.

The dome-like chambers may have been developed both in stratified rocks and in breccia-pipe structures. Some of these chambers have been open to the surface above by collapse and now are karst windows called with names like “Grotta sfondata” (smashed down cave), “Grotta due occhi” (two eyes cave).

The emptying of the breccia-pipes may be helped by hydrological activity inside the breccia body, especially by the water circulation near the contact breccia and solid limestone.

A PRELIMINARY MODEL OF THE GENESIS OF THE DOME-LIKE CAVES

A preliminary model of the genesis of the domelike caves may be so outlined:

- 1) during the Miocene desiccation of the Mediterranean, karst speleogenesis with development of large caves far below the present sea level; the block tectonic of the morphostructure could have favoured the water circulation also inside low permeability rock units; some caves could have developed along lithological and erosional discontinuities, as latheritic crusts;
- 2) development of breccia-pipes following the collapse of the caves roofs and their propagation upward;



Fig. 1: A breccia pipe cut by the coastal cliff south of Testa del Gargano (photo U. Sauro).



Fig. 3: The karst window of Grotta Sfondata, a dome-like marine cave developed inside a breccia-pipe (photo U. Sauro).



Fig. 2: Detail of a breccia-pipe exposed on the coastal cliff (photo U. Sauro).

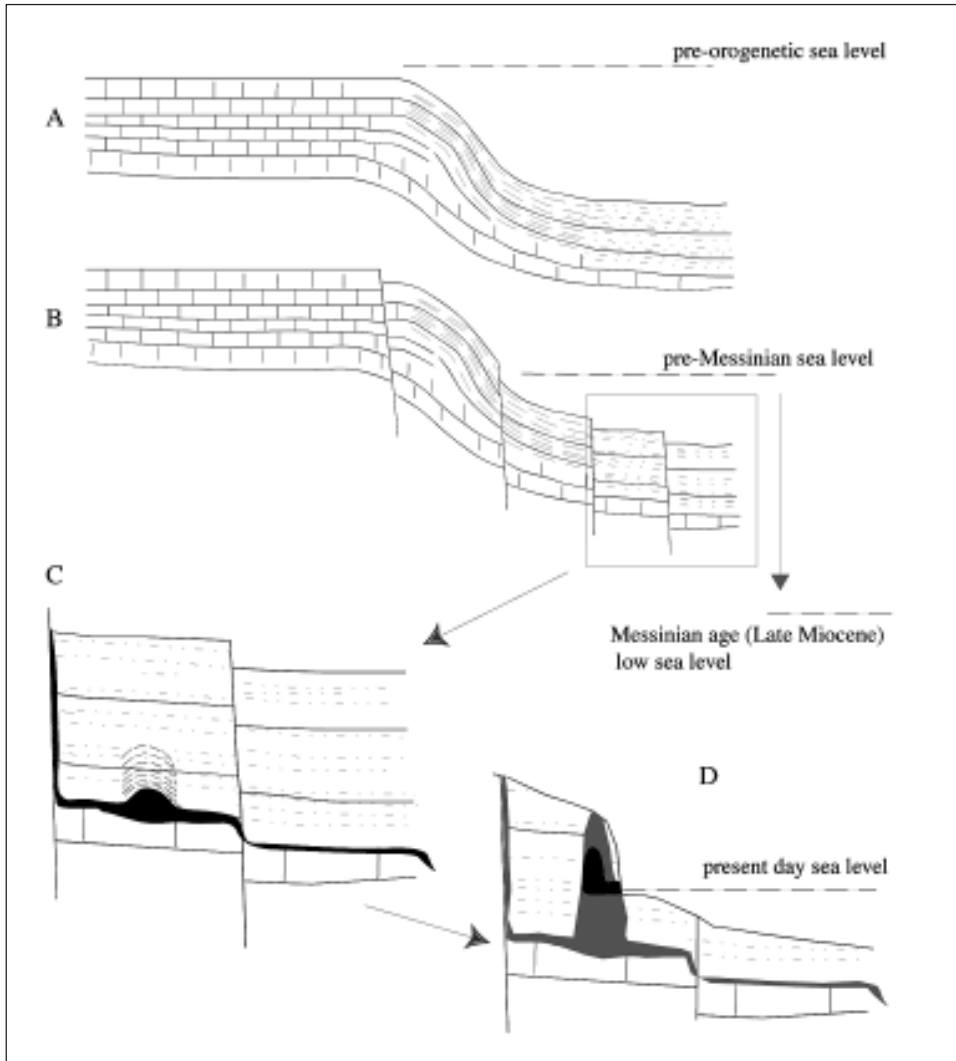


Fig. 4: Preliminary model of the genesis of breccia-pipes and of dome-like caves:

A) accretion of the margin of Apulian outer platform during the Cretaceous and sedimentation of different carbonatic formations;

B) uplift and building of the morphostructure of the Gargano plateau as foreland of the Apenninic chain; during this structuration, lowering of the sea-level due to the upper Miocene desiccation of the Mediterranean;

C) karst speleogenesis of large caves far below the present sea level and development of karst breccia-pipes by collapse of the cave roofs;

D) intersection of the breccia-pipes by the withdrawing coastal cliff and dissection and partial emptying of some breccia-pipe structures with development of a peculiar type of coastal cave.

- 3) dissection and partial emptying of some breccia-pipe structures by withdrawal of the marine cliff with development of a peculiar type of coastal cave and sometime of karst windows. Inter-disciplinary research may help to test this preliminary model.

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Povzetek

Razvoj nekaterih jam v obalnih stenah polotoka Gargano je odvisen od prisotnosti kraških brečastih cevi. Če te cevi, ki lahko predstavljajo tudi vodonosnike, prerežejo obalne stene, jih lahko izprazni udarni valovi. Na ta način se lahko razvijejo kupolaste jame, ki se včasih odpro na površje. Prispevek predstavlja model geološke in geomorfološke zgodovine, s pomočjo katerega je mogoče razložiti nastanek brečastih cevi in omenjenih jam.

Ta predhodni model nastanka kupolastih jam si zamišljamo takole:

1. Ko je bilo v miocenu Sredozemlje skoraj izsušeno, je segala kraška speleogeneza, vključujoč velike jame, daleč pod današnjo morsk gladino; morfostrukturalna tektonika blokov je omogočala kroženje vode tudi v kamninskih blokih z nizko prepustnostjo; nekaj jam se je lahko razvilo vzdolž litoloških in erozijskih diskontinuitet, kot so npr. lateritske skorje.
2. Razvoj brečastih cevi je sledil udiranju jamskih stropov in njihovi rasti navzgor.
3. Umik obalnih sten je nekatere brečaste cevi prerezal in izpraznil in nastale so obalne jame nenavadnega tipa, včasih tudi kraška okna.

Interdisciplinarne raziskave bi lahko pripomogle k preizkusu tega predhodnega modela.

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