The karst geomorphology of the Boukadir region (Chelif – Algeria)

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Abstract

In June 1988, in the region of Boukadir, northwestern Algeria, a large collapse 60 m in diameter and 35 m deep occurred in the National Road RN4. This region was not considered as strongly exposed to a geotechnical karst hazard. However, this collapse sinkhole suggests that there are large underground cavities under the Quaternary alluvium of the Boukadir plain, at an altitude near or lower than the present sea level. Geological analysis reveals that the Lithothamnium limestones outcropping on the northern Ouarsenis piedmont extend under the Quaternary alluvium. The surface karstic morphology is not spectacular because of the friable nature of this carbo nate platform, but a deep collapse sinkhole called "Bir Djeneb" or "Puits du Diable" was evidenced. The underground voids below the plain could be the result of the base level drop during the Messinian Salinity Crisis (MSC) which let an imprint on the marginal platforms of the Mediterranean Basin.

Résumé

Deux dolines d'effondrement dans la région de Boukadir (Algérie). En juin 1988, dans la région de Boukadir, au Nord-Ouest de l'Algérie, un large effondrement de 60 m de diamètre et 35 m de profondeur s'est produit sur la RN4. Cette région n'était pas considérée comme fortement exposée à l'aléa géotechnique typique du karst. Ce gouffre d'effondrement suggère cependant qu'il existe de grands vides souterrains sous les alluvions quaternaires de la plaine de Boukadir à une altitude proche ou inférieure à celle de la mer. L'analyse géologique révèle que les calcaires à Lithothamnium qui affleurent sur le piémont nord de Ouarsenis se prolongent sous les alluvions quaternaires. La morphologie karstique de surface n'est pas spectaculaire à cause de la nature friable de cette plateforme carbonatée, mais une profonde doline d'effondrement y a été mise en évidence, « Bir Djeneb » ou « Puits du Diable ». Les vides souterrains sous la plaine pourraient être le résultat de l'abaissement généralisé des niveaux de base pendant la crise de salinité messinienne (MSC), qui a laissé son empreinte sur les plates-formes marginales du bassin méditerranéen.

1. Introduction

Karstic carbonate landscapes are directly linked to climate and relief. These two variables offer large variations in Algeria (COLLIGNON, 1991).

Knowledge in Algeria about karstic landscape is restricted, though their study is important for several reasons. This study focuses on the marginal Messinian carbonate platform outcropping (Fig. 1), in the northern piedmont of Ouarsenis mountains. It is in the Boukadir region, northwest of Algeria, on the southern edge of the 20 km wide lower Chelif plain crossed by the Chelif River. There is a lack of knowledge in karst geomorphology about this carbonate platform. On June 16th, 1988, a large collapse pit occurred about 1 km north of the Ouarsenis piedmont, in the Chelif Basin (OURABIA & BENNALLAL, 1989). It broke the national road RN4 that connects the Capital Algiers to the city of Oran in west. At the level of the foothills, there is another large collapse sinkhole perched high up called "Bir Djeneb" or "Puits du Diable". The aim of this paper is to unravel processes that lead to the formation of these collapse sinkholes, by combining geology, speleology, and geomorphology.

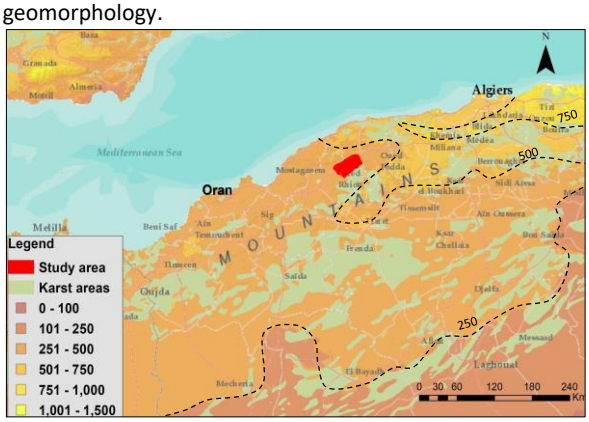

Figure 1: Karstic areas of Algeria and the study area. Mean annual rainfall (mm/year). Esri Copyright © 1995–2022 Esri.

2. Materials and methods

The geology is studied by analysing the lithological characteristics of this region, the drilling made by the Central Laboratory for Public Works (LCTP) on 20-05-1989, and the geological cross section drawn by SCET-AGRI (1985). The speleological study is based on the report of BIREBENT (1947), entitled Speleology of Algeria: Inventory, where the author made an inventory of the caves of the regions. The geomorphological analysis is based on field work, Google Earth images, and aerial photographs.

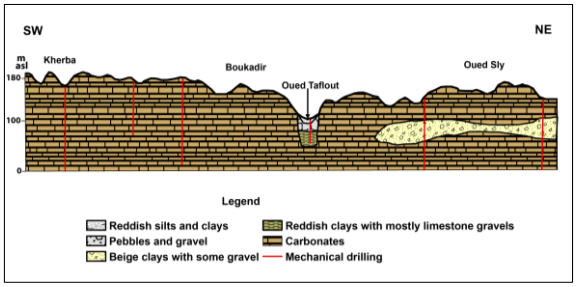

Figure 2: Reinterpreted geological cross-section based on 6 mechanical drill cores parallel to the piedmont and across Oued Taflout (SCET-ARGI, 1985). The section shows a ~ 70 m deep Messinian incision at the location of Oued Taflout filled first by ~40 m of clay and then by coarser alluvial deposits.

3. Results

3.1. Geology

The Ouarsenis piedmont is composed of Messinian carbonates outcropping in the form of a large monoclinal slab, south of the Chelif valley (Boukadir region). It is composed of 3 main geological units. The basal up to 500 m thick Tortonian to Messinian blue marls are overlain by two Messinian bioclastic carbonate units having low dips (NEURDIN- TRESCARTES, 1992; MOULANA *et al*., 2021). The lower bioclastic carbonate unit is an up to 70 m thick heterogeneous bioclastic carbonate unit. It is overlain by the upper unit comprising at least 80 m of homogeneous Lithothamnium carbonate packstones. In the Chelif Plain, the S1 drill hole reveals that the top unit is a 22.5 m thick alluvial formation composed of clayey silty and sandy conglomerate and corresponds to the Quaternary surface aquifer. Then, unit 2 is a 26.2 m thick layer of brown clay. It corresponds to a Pliocene aquiclude that separates the alluvial aquifer from the limestone aquifer which starts at the depth of 61 m. The geological cross-section (SCET-ARGI, 1985) parallel to the piedmont and across Oued Taflout, evidenced a 70 m deep incision in the carbonate at the level of the present river Oued Taflout (Fig. 2). The incision is filled by a basal brown clay unit, then by an alluvium unit. The top layer consists in silt and red clay.

3.2. Speleology

BIREBENT (1947) describes five caves in the carbonate massif of the piedmont of the Ouarsenis. Bir Djeneb is the most considerable karstic feature of the studied area (Fig. 3). Located 5.5 km SW of Boukadir. It is a cylindrical pit about 20 m in diameter and 63 m deep (Fig. 3). It is dug mainly in the soft Messinian carbonate. At the top, colluvium is made of pebbles with little matrix outcrops and below more clay-rich sediments. In the bottom, a narrow conduit in the lower bioclastic carbonate unit about 3 m in diameter goes down with a faint slope to 73 m deep. The bottom of the main shaft is made of scree. The latter ends to a second pit, much smaller than the first one, 5 m deep and 3 m in diameter. In 2021, a new exploration evidenced the continuous infilling of the pit that reaches the depth of 53m.

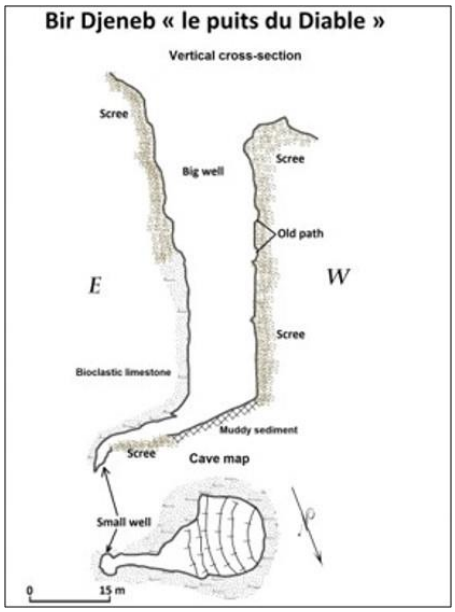

Figure 3: Map and cross-section of Bir Djeneb cave, northern Ouarsenis piedmont; after BIREBENT (1947), modified.

3.3. Geomorphology

The geomorphological analysis reveals that the most frequent karstic dissolution features are small shelter-caves; they are more frequent in the lower bioclastic carbonate unit than in the upper Lithothamnium unit. Their interior is composed of pinkish white tuffaceous limestones, and their external roof is composed of a thin layer of hard and compact limestones. We also notice the occurrence of landslides in association with shelter-caves hanging on the steep valley walls high above the present riverbed due to the breaking of their roof (Fig. 4). We observed few vertical swallow holes dug in the top calcrete in the east. Some rare ponors are evidenced. A few large resurgences, in the west end of our study area are distinguished.

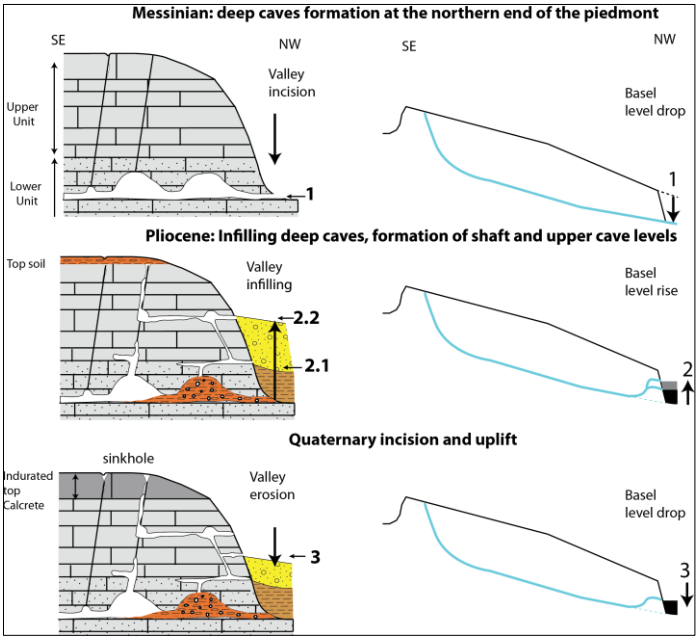

Figure 4: Drawing of the northern piedmont of the Ouarsenis representing. 1. Valley incision and deep void formation during the Messinian Salinity Crisis (MSC). 2 Infilling of deep caves and formation of shafts during the Pliocene. The clay-rich infill is evidenced in Figure 2 in caves and valleys and is followed by a valley alluvium infill. 3. Tectonic uplift and lowering of the base level during the Quaternary leading to river incision.

4. Discussion

The results of the geological and the geomorphological analyses show that the current surface weathering and the deep active karstification are relatively limited. Infiltration is restricted by the present-day top calcrete. However, caves and shelter-caves resulting partly from river incision imply a sizable karstic network (or endokarst).

The 35 m deep 1988 collapse occurred through a thick pile of sediments. The beds of the collapsed terrain are unconsolidated and made of relatively insoluble material. They are not karstic, but we infer that the phenomenon is fully karstic. Messinian carbonates, that outcrop 1.5 km more to the south, lie at 61 m depth and a gigantic void must have existed in this formation to let the place for a falling in of at least 95 000 cubic meters. In addition of the RN4 shaft, there exist another imprint of an active karstification of the Messinian carbonates: “Bir Djeneb”. This collapse shaft suggests that the piezometric base level was quite deeper than the present one. The last possible occurrence of such low base level is during the Messinian itself. Indeed, during this period, the climate was hot and dry (FAUQUETTE *et al.*, 2006), so a strong evaporation occurred, triggering a fall of the Mediterranean Sea level to about -1500 m (RYAN, 1976). Around the Mediterranean Sea, rivers cut deep canyons to adapt to this low base level (CLAUZON, 1982; JULIAN & NICOD, 1984; BINI, 1994; BOURILLOT *et al.*, 2010; KRIJGSMAN *et al.*, 2018). It is considered here that the large underground cavities at Boukadir along the southern margin of the Chelif valley were formed during this MSC, even though the collapse sinkhole of Bir Djeneb, has no simple link with the eustatic variations.

5. Conclusion

The karst pattern in the investigated carbonates is relatively undeveloped. The high porosity of the Lithothamnion carbonates favours diffuse infiltration rather than the widening of fractures, which reduces localized dissolution and flow, and impedes the development of large caves. Boukadir karsts are characterized by a low present-day activity. The endokarst is relatively poorly developed whereas the epikarst is prevalent and characterized by shelter caves. The large voids deep below the present-day base-level on the southern edge of the Chelif Plain are inferred to be a paleokarst related to the Messinian Salinity Crisis who lowered the Mediterranean Sea level. These are responsible for the collapse hole of RN4, in 1988, which has a convergence of forms with the collapse sinkhole of Bir Djeneb (collapse sinkhole of a few tens of meters) (Fig. 5). However, the link of Bir Djeneb with the MSC, is not evident. The genetic relation of the two holes thus remains problematic.

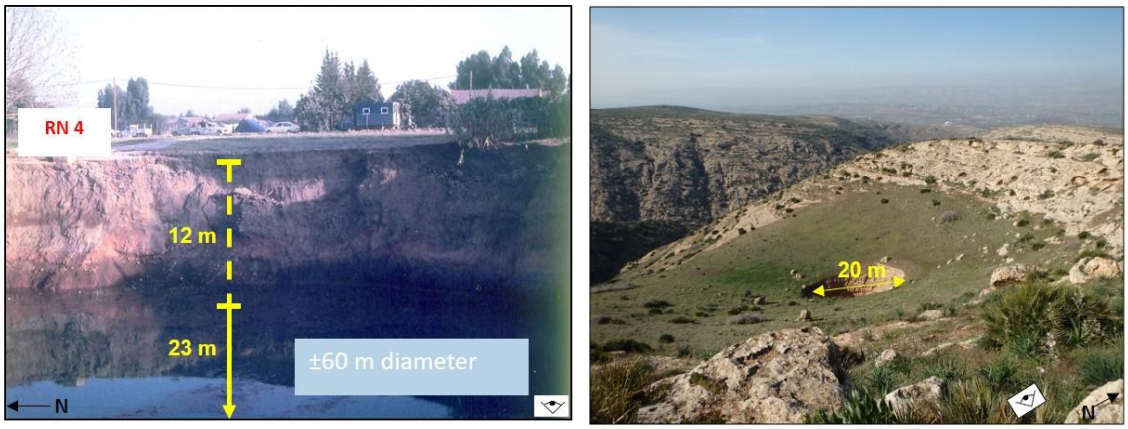

Figure 5: The 2 major sinkholes in the study area. Left: the 1988 RN4 sinkhole in the Chelif Basin 500 m from the carbonate piedmont (Photo taken by Pr. Mostefa GUENDOUZ on 16/06/1988). Water table is 12 m below the level of the road. Right: The Bir Djeneb in the carbonate Ouarsenis Mts.

Acknowledgments

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References

Bini A. (1994) Rapports entre la karstification périméditerranéenne et la crise de salinité du Messinien. Karstologia, 23, 33-53.

Birebent, J. (1947) Spéléologie de l'Algérie : Inventaire. Agence National des Ressources Hydraulique. Alger, le 1er Décembre 1947. Rapport.

Bourillot, R., Vennin, E., Rouchy, J. M., Blanc-Valleron, M. M., Caruso, A., & Durlet, C. (2010) The end of the Messinian salinity crisis in the western Mediterranean: Insights from the carbonate platforms of south-eastern Spain. Sedimentary Geology, 229(4), 224-253.

Clauzon, G., Suc, J. P., Gautier, F., Berger, A., & Loutre, M. F. (1996) Alternate interpretation of the Messinian salinity crisis: Controversy resolved? Geology, 24(4), 363-366.

Collignon, B. (1991) Les principaux karsts d'Algérie. Quelques éléments de synthèse, actes du 9ème Congrès National de la SSS., Akten des, 9.

Fauquette, S., Suc, J.P., Adele Bertini, A., Popescu, S.M., Warny, S., Bachiri Taoufiq, N., Perez Villa, M.J., Chikhi, H., Feddi, N., Subally, D., Clauzon, G., Ferrier, J. (2006) How much did climate force the Messinian salinity crisis? Quantified climatic conditions from pollen records in the Mediterranean region. Palaeogeography, Palaeoclimatology, Palaeoecology, 238(1-4), 281-301.

Julian, M., & Nicod, J. (1984) Paléokarsts et paléo-géomorphologie néogènes des Alpes Occidentales et régions adjacentes. Karstologia, 4(1), 11-18.

Krijgsman, W., Capella, W., Simon, D., Hilgen, F. J., Kouwenhoven, T. J., Meijer, P. T., ... & Flecker, R. (2018) The Gibraltar corridor: Watergate of the Messinian salinity crisis. Marine Geology, 403, 238-246.

LCTP (1989) Effondrement de la RN4. Oued Sly (Boukadir) Chlef. Laboratoire Central des Travaux Publics d'Alger. Rapport.

Moulana M. L, Hubert-Ferrari A, Guendouz M, El Ouahabi M, Boutaleb A & Boulvain F (2021) Contribution to the sedimentology of the Messinian Limestones of Boukadir (Chelif Basin-Algeria); Geologica Belgica. 24/1-2 : 85-104. DOI : 10.20341/gb.2021.002.

Neurdin-Trescartes, J. (1992) Le remplissage sédimentaire du bassin néogène du Chelif, modèle de référence de bassins intramontagneux (Doctoral dissertation, Pau).

Ryan, W. B. (1976) Quantitative evaluation of the depth of the western Mediterranean before, during and after the Late Miocene salinity crisis. Sedimentology, 23(6), 791-813.

Scet – Argi (1). (1985) Hydrologie – Hydrogéologie et bilan des ressources, Etude du réaménagement et de l'extension du périmètre du moyen Chéliff : Rap A1.1. 2. Pub. Ministère de l'Hydraulique. 72 p.