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Hypogene speleogenesis in the Cenozoic carbonates of the Prichernomorsky artesian basin (north Black Sea region)

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Abstract: *This paper demonstrates the dominant hypogenic origin of caves and other karst features in the Prichernomorsky artesian basin, a major hydrogeological structure of the north Black Sea region. The basin occupies the south of the continental part of Ukraine and the north-central plain part of the Crimea Peninsula and is dominated by the Neogene (lower Pliocene through upper-middle Miocene) and Paleogene (Eocene through Paleocene) carbonate rocks, intercalated with sands, sandstones, clays and marls. The key study areas, in which some limestone members are exposed and partially drained, lie in the opposed sides of the basin: the north Black Sea region in the continental part (caves in lower Pliocene and Miocene limestones) and the Inner Range of the fore-mountain Crimea in the south, where the basin borders with the fold-trust Alpine mountain region (caves in Eocene and Paleocene limestones). The hypogenic origin of caves is strongly suggested by the analysis of cave morphology and occurrence relative to lithostratigraphy and structural features, cave sediments, isotopic and mineralogical data, and paleohydrogeological analysis. Despite of differences in age and diagenetic maturity of the host rocks, the caves demonstrate remarkable common features imposed by their common origin. The hypogenic speleogenetic model well explains observed specific hydrogeological and geochemical features of the regional multi-storey aquifer system in the central confined part of the basin. Hypogene speleogenesis is likely to play a role in the formation of carbonate-hosted reservoirs, as well as in the migration and accumulation of hydrocarbons in the Prichernomorsky basin.*
Keywords: *Karst, Hypogene speleogenesis, Black Sea Basin, Ukraine.*

The Prichernomorsky (Black Sea) artesian basin

The Prichernomorsky artesian basin is a major hydrogeological structure of the north Black Sea region, occupying the south of the continental part of Ukraine and the north-central plain part of the Crimea Peninsula (Fig. 1). It roughly corresponds to the Prichernomorsky tectonic depression developed during Cretaceous-Paleogene on the Arhean-Mesoproterozoic basement of the Eastern-European Platform (within the continent) and the neoproterozoic-Early Triassic basement of the Scythian Plate (within the Crimea Peninsula). The upper part of the sedimentary cover is comprised by the Neogene (lower Pliocene through upper-middle Miocene) sequence of intercalated limestones, sands, clays and marls. The sequence lays on Paleogene (Eocene through Paleocene) and Cretaceous carbonate and clay deposits. The Neogene sequence hosts an extensive multi-story aquifer system, with aquifers in limestones and sands separated by leaky aquicludes comprised by clays and marls (Lushchik, Lisichenko, Yakovlev, 1988). Subaerial clays of Pliocene age form the upper confining unit. The confining cover and the upper aquifer units are incised by erosion and partially drained throughout the large part of the basin (Fig. 1A). Aquifers in carbonate members of the Paleogene and Cretaceous succession are less extensive and overall confined except of the southern edge of the basin. In the southern edge in

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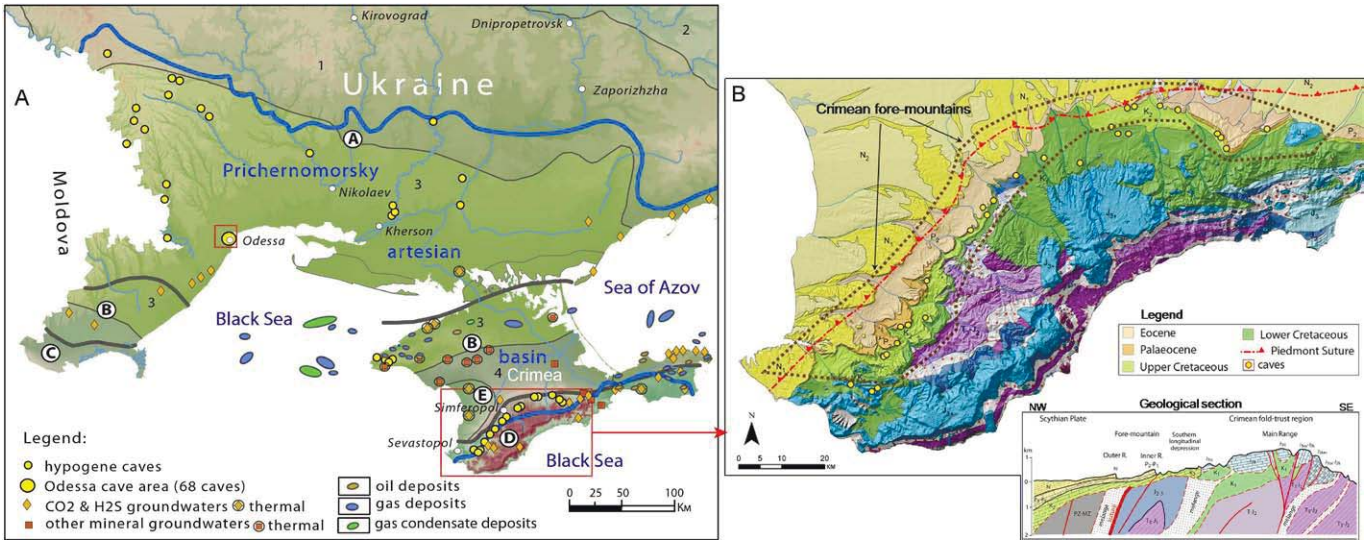

Fig. 1. A - Hypogene caves and relevant hydrogeologic features in carbonate successions in the Prichernomorsky artesian basin, South Ukraine. Major tectonic structures (circled characters): A - Eastern-European Platform (pre-Rifean); B - Scythian Plate (epi-Paleozoic); C - North Dobrogea fold-thrust region (Hercynian); D - Crimean foulded region (Kimmerian-Alpine); E - Crimean foredeep (Kimmerian-Alpine). Other tectonic structures: 1 - Ukrainian Shield; 2 - Dnieper-Donetzk Depression (Mesozoic); 3 - Prichernomorsky Depression (Cretaceous-Paleogene); 4 - Central-Crimean Uplift (Cretaceous-Paleogene). B – Geologic map of the southwest part of the Crimean Peninsula and schematic geologic profile (after Yudin, 2008).

Crimea, the basin borders with the Crimean Mountains (the Alpine fold-thrust region) and encompasses the cuesta-like Outer and Inner Ranges of the Crimean fore-mountains (Fig. 1B). Along the Inner Range, the Neogene rocks are eroded away and Paleocene and Eocene limestones are uplifted and tilted at 5-20 degrees, forming a northwest-dipping monocline and southeast-facing cuesta scarps.

Karst features occur in Pontian (Early Zanclean), Meotian (Late Messinian) and Sarmatian (Early Messinian) limestones of the Neogene system. In Paleocene and Eocene limestones, deep-seated cavities and karstified zones are known from borehole data in the Plain Crimea part of the basin. In the fore-mountain Crimea, accessible caves, karstified fractures, numerous grottoes and clusters (zones) of cavernosity in these limestones are abundantly displayed in the cuesta scarps of the Inner Range.

Karst in the region has been previously interpreted in the framework of the traditional epigenic paradigm, with deep-seated features being regarded as paleokarst. Recent studies, however, strongly suggest that hypogene speleogenesis is the region-wide process responsible for the formation of conduits, caves and cavernous zones, presently relict in the areas where limestones are uplifted and drained, and still developing in the confined areas.

Odessa Region: Karst in lower Pliocene Limestones

The most instructive type area for studying speleogenesis in the Pontian limestones is the Odessa city in the south of the continental Ukraine (see Fig. 1, A for location), where extensive ancient underground mines (locally called ‘catacombs’) intercept numerous karst caves and karstified fractures. 68 intercepted caves with total length of about 7,150 m are documented there, including 7 caves with individual lengths of over 300 m and two caves longer than 1 km (Pronin, 2009). The most outstanding features of these caves are their complete lateral isolation and apparent irrelevance to the surface (Fig. 2), which rules out any possibility of their formation by lateral flow and surface recharge. Caves are fracture-controlled, single linear passages, or clusters of intersecting passages, blind-ended in every lateral direction.

The analysis of cave morphology and sediments (Klimchouk, Pronin & Timokhina, 2010) has firmly established that the caves had been formed under shallow leaky confined conditions by waters rising across the Pontian limestones from deeper aquifers and mixing with lateral shallow flow along certain beds, which caused renewal of the aggressiveness. Similar caves are known in the south-west of Ukraine and Moldova where the Pontian and Sarmatian limestones are incised by erosional valleys.

The Fore-Mountain Crimea: Karst in Eocene and Paleocene Limestones

The type area for studying origins of solution porosity in the Eocene and Paleocene limestones is the Inner Range of fore-mountain Crimea in the southern edge of the basin, where these limestone beds form distinct cuestas (Fig. 1B). Recent studies have revealed ample and systematic evidences that caves are of hypogenic origin, and that most of solution features in the scarps are remnants of morphologies of caves and karstified

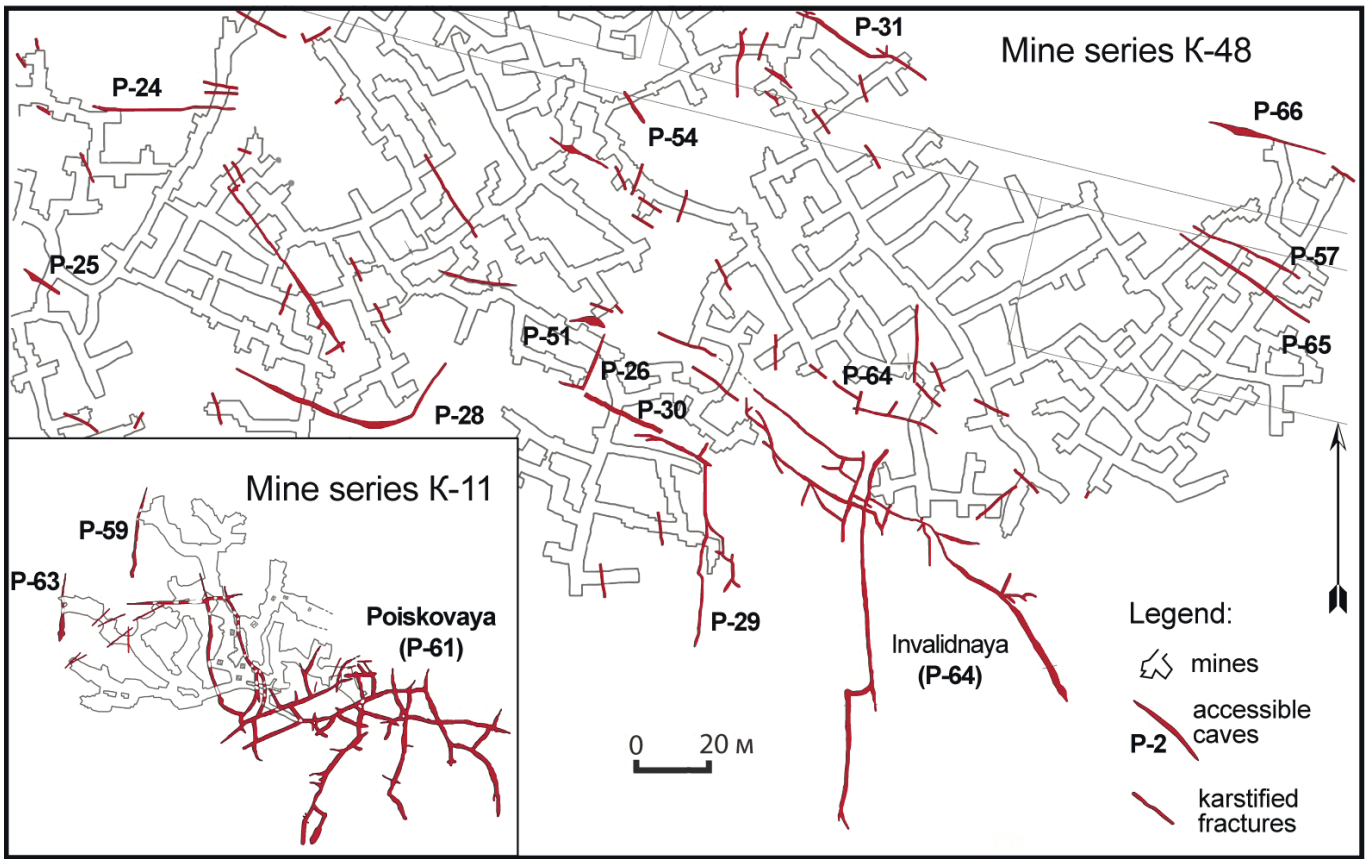

Fig. 2. Distribution of caves (red lines) intercepted by ancient mines (grey lines) in the Pontian (lower Pliocene) limestones in the Odessa region, south Ukraine (modified after Pronin, 2009).

fractures, the walls of which are now exposed due to block-fall retreat of the scarp faces (Klimchouk, Timokhina & Amelichev, 2009). The solution features in various beds demonstrate strong lithostratigraphic control in their distribution and are vertically stacked into transverse complexes (Fig. 3). Caves are fracture-controlled, linear, or crude maze clusters, demonstrating the complete suite of speleomorphs indicative of hypogenic origin (Klimchouk, 2007). Isolated cavities, observed in the contemporary scarps as grottoes and niches, as well as zones of spongework porosity (cavernous zones), develop where laterally conductive beds of high initial porosity are crossed

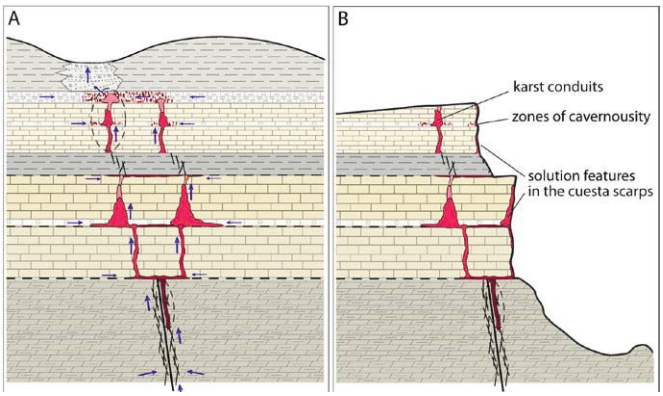

Fig. 3. Conditions of the formation (A) and the current geomorphic situation (B) of caves and other karst features in the Inner Range of the Crimea fore-mountains.

by penetrating vertical fractures that once conducted rising fluids from a regional flow system (Fig. 4A). Large linear fault-related rift-type conduits in the underlying Upper Cretaceous marls, that served as feeding 'roots' for hypogenic caves in the limestones above, have been recently documented in the foot of some cuestas. Besides the cave morphology, the hypogenic origin of the caves is corroborated by the isotope alteration halo in the host rocks (Dublyansky et al., 2011) and by recent finding of a massive crust of phreatic columnar calcite and a hydrothermal mineral stibnite in some caves. The abundance, outstanding expression, preservation and accessibility of relict hypogene karst features in the extensive cuesta exposures of the Inner Range makes the latter a foremost region for studying regularities of hypogene solution porosity development, the process currently ongoing in the adjacent artesian basin of the Plain Crimea.

Concluding remarks

Regional cave studies and analysis of hydrogeological and geochemical features of the regional aquifer system throughout the basin (Fig. 1A) reveal the basin-wide role of hypogene speleogenetic processes in the development of solution porosity and permeability in carbonate rocks. In spite of some distinctions imposed by tectonic position and local structural features, hypogene caves in limestones of different age and of

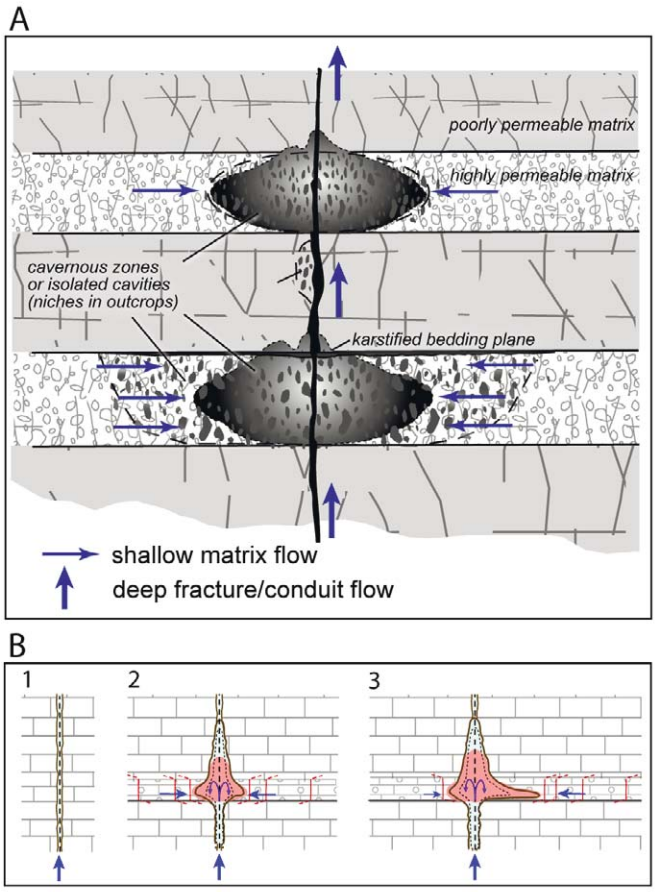

Fig. 4. Conceptual models of the speleogenetic effects of dissolution due to mixing of the upwelling deep flow along a sub-vertical fracture conduits with shallower lateral flow along beds of high pore matrix permeability. A - Formation of cavernous zones and isolated cavities, B - Symmetric (2) and assymmetric (3) widening of an original fracture conduit (1) along the bed of high matrix porosity and permeability.

different degree of diagenetic maturity and pre-speleogenetic matrix porosity, have some remarkable common features in occurrence and morphology. The main speleogenetic process, clearly discerned from hydrostratigraphic/ structural relations and morphology of caves, is renewal of aggressiveness due to mixing of deep vertical and shallow lateral flow in the confined aquifer system (Fig. 4). Dissolution by rising thermal waters and by sulfuric acid (due to oxidation of H_2S) is also likely to play a role, at least locally.

The Plain Crimea part of the Prichernomorsky artesian basin is known to be an area of hydrothermal and mineral groundwater resources. We argue that thermal and chemical anomalies of groundwaters in the stratified predominantly carbonate succession in the basin are related to the development of transverse high permeability zones, one of the prime results of hypogene speleogenesis. Another result is the high degree of hydraulic connection between individual aquifers in the multi-story aquifer system, a characteristic feature of regional hydrogeology (Lushchik, Lisichenko, Yakovlev, 1988). Hypogene speleogenesis is also likely to play a role in the formation of carbonate-hosted reservoirs, in the migration and accumulation of hydrocarbons in the Prichernomorsky basin.

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References

Dublyansky, Yu., Klimchouk, A., Timokhina, E., Spotl, C. 2011. Isotopic indications of water-rock interaction in the hypogene Tavrskaya cave, Crimea, Ukraine. *Geophysical Research Abstracts,* 13, EGU2011-3055.

Klimchouk, A.B., 2007. *Hypogene Speleogenesis: Hydrogeological and Morphogenetic Perspective*. NCKRI Special Paper 1. Carlsbad: National Cave and Karst Research Institute, p. 106.

Klimchouk, A.B., Pronin, K.K., Timokhina, E.I., 2010. Speleogenesis in the Pontian limestones of Odessa. *Speleology and Karstology,* 5, 76 – 93. (in Russian).

Klimchouk, A.B., Timokhina, E.I. & Amelichev, G.N., 2009. Hypogene Speleogenesis in the Piedmont Crimea Range. In Klimchouk, A. & Ford, D., eds, Hypogene Speleogenesis and Karst Hydrogeology of Artesian Basins, UISK Special Paper 1, Simferopol, Ukraine.

Lushchik, A.V., Lisichenko G.V., Yakovlev, E.A., 1988. *Formirovanie rezhima podzemnykh vod v rayonakh razvitiya aktivnykh geodinamicheskikh processov* [*The Formation of a Regime of Groundwaters in Regions of Active Geodynamic Processes*]. Naukova dumka, Kiev, p. 160. (in Russian).

Pronin, K.K., 2009. *Natural Caves of the Prichernomorsko-Azovsky and Moldavsko-Podolsky Karst Regions*. Ukrainian Institute of Speleology and Karstology, Simferopol, p. 104. (in Russian).