Late Pleistocene vegetational history and ecosystem variability in the karst areas of Ukraine, based on palaeontological studies of cave deposits

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Biotic response to Late Pleistocene climate changes has been studied in four sections of clastic cave deposits in two areas of Ukraine: in the western Podillya-Bukovynian gypsum karst region and the southern Mountain-Crimean carbonate karst region (Fig.1). New data have been obtained in the Bukovynka and Emine-Bair-Khosar caves, previously studied (Vremir et al., 2000, 2005; Ridush, 2009, 2014; Ridush et al., 2013; Gerasimenko et al., 2010, 2014, 2015), whereas deposits at the Kryshtaleva and Tovtry caves are studied palynologically for the first time. A lithological study, including grain-size analysis, has been also applied at all sites, and its palaeoenvironmental interpretations correspond well to those derived from pollen and palaeofaunal data.

The oldest deposits represent the Last Interglacial, as evidenced from the pollen succession and pollen percentages of broadleaf taxa that exceed those of the present. Telocratic and mesocratic phases of an interglacial (Quercetum mixtum and Carpinetum, respectively) are clearly expressed. In both areas, a special characteristic of the vegetation is the occurrence of *Fagus*, whereas in the western area (the Tovtry Cave), it is also the abundance in Ericaceae, and the admixture of *Picea* and *Pinus cembra* at the beginning of the interglacial. In the mountain meadow-steppe of Crimea, petrophytic vegetation included *Scorzonera* and *Ephedra,* whose abundance increased strongly during the Last Glacial. In the interglacial cave deposits, bones of *Cervus elaphus* dominate in Crimea, though remains of open-area animals (*Bison priscus, Bos primigenius* etc) also occur, whereas bones of forest dormice (*Dryomys nitendula*) are found in the western Tovtry Cave.

In deposits of all the caves, alternation of the Last Glacial interstadials and stadials is clearly marked,respectively, by the appearance and disappearance of pollen of broadleaf trees. Their refugia evidently existed on the Crimean mountain slopes and in the canyon-like valleys of the River Dniester and its tributaries. Pollen of broadleaf trees are also found in coprolites of troglophile carnivores. During the interstadials of the Early Glacial and in the interval between 48,500±2,000 and >42,000±1,200 BP, the western karst area was covered by mixed forest, whereas only patches of woods existed at the edge of the mountain meadow-steppe in Crimea. Polypodiaceae ferns grew extensively here. During the later interstadials (around 41,300±1,300/1,100 and between 33,100±400 and 27,700±250 BP), the extent of arboreal vegetation was much smaller in both areas (forest-steppe in the west and mesophytic steppe in the upper part of the Crimean Mountains). In the west, during the interstadial of 41,000 BP, there lived both steppe (*Equus ferus latipes, Bison priscus, Megalocerus giganteus)* and forest *(Sus scrofa, Vulpes vulpes)* large mammals, as well as cave inhabitans (*Crocuta spelaea, Ursus ingressus*). During the Early Glacial and Middle Pleniglacial stadials, tundra-forest-steppe (with an abundance of arcto-boreal forms of club-mosses and *Botrychium boreale*) existed in the west, whereas Poaceae-Cyperaceae associations and extensive patches of *Ephedra* formed the highest vegetation belt of the Crimean Mountains. There, during the

Middle Pleniglacial, the forest animals were *Cervus elaphus, Felis sylvestris, Martes sp., Sicista cf. betulina* and *Apodemus sylvaticus*, whereas the steppe animals included *Equus ferus latipes, Equus hidruntinus*, *Bison priscus, Bos primigenius, Saiga tatarica, Vulpes corsac*, *Mustella eversmanii*, *Marmota bobac*, *Microtus arvalis*, *Spermophilus sp.*, and inhabitans of periglacial landscapes: *Mammuthus primigenius, Coelodonta antiquitatis, Alopex,* and *Microtus oeconomus.* Optimal phases of spread of broadleaf vegetation during the Last Interglacial and the interstadials were characterized by the accumulation of clay particles in the clastic cave deposits, whereas the stadial deposit are marked by an increase in large silt particles.

The Late Pleniglacial deposits are represented only in the western karst area (the Kryshtaleva Cave), where they are characterized by the lowest pollen percentages of trees and the highest percentages of cryophytes including *Betula* sect. Nanae et Fruticosae. A treeless periglacial tundra-steppe occupied the area. Poaceae and Cyperaceae prevailed in the vegetation cover, together with arcto-boreal plants (*Lycopodium dubium, Diphazium alpinum, Botrychium boreale*), though Asteraceae, Lamiaceae and *Ephedra* were also rather significant. Bones of *Rangifer tarandus, Alopex, Dicrostonyx torquatus*, and *Lagopus lagopus* are evidenty related to these (Late Pleniglcail) sediments as they are overlain by dated Late Glacial deposits. Large silt particles in the latter are half those occurring in the Late Pleniglacial sediments. This might indicate frequent dust storms and loess deposition on the surface during the Pleniglacial.

Fig. 1 Site location.

Late Glacial deposits in the caves Kryshtaleva, Bukovynka and Emine-Bair-Khosar have yielded ^{14}C-dates 12,240±70, 12,050±60, 11,890±60, 11,710±60, 10,720±60, 10,490±70 BP. Their common characteristic in both areas is the increase in arboreal pollen, as compared to the Pleniglacial. During the Bölling-Alleröd, boreal trees (particularly pine) dominated on the left bank of the Dniester River valley, whereas on its right bank (closer to the Carpathians), a few broad-leaved trees appeared (*Ulmus* and *Corylus*), as well as in the highest forest belt of the Crimean Mountains (*Acer* and *Fagus*). During the Young Dryas, on the left bank of the Dniester, mesophytic steppe existed and a few cryophytes re-appeared (*Betula* sect. Nanae et Fruticosae), whereas the right bank of the Dniester was occupied by boreal forest-steppe. Meadow-steppe dominated at the high levels of the Crimean Mountains, but a few broadleaf trees continued to grow. The proportion of clay particles in the Young Dryas deposits is less than that in Late Glacial interstadial sediments. At the beginning of the Late Glacial, *Ursus*

arctos appeared in the western area, but *Rangifer tarandus* was still present. In the Crimean Mountains, the diversity of large mammals decreased due the disappearance of the periglacial elements. The forest animals included *Cervus elaphus, Ursus arctos, Felis* sp. and *Apodemus cf. flavicollis*. Steppe species dominated during the Young Dryas: *Saiga tatarica, Bison priscus, Vulpes corsac, Lepus europaeus, Mustella eversmanii, Cricetus cricetus, Microtus arvalis, Eolagurus luteus*, and *Lagurus lagurus*. The faunal assemblage, as well as the pollen data, indicate a drier climate than nowadays.

Thus, this multidisciplinary study in two karst areas proves that clastic cave deposits record the global climatic signal and show regional ecosystem variability.