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Pollen records of mardel deposits: The effects of climatic oscillations and land management on soil erosion in Gutland, Luxembourg

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ABSTRACT

Typically for the geomorphology of the Luxembourger Gutland is the occurrence of mardels, a local name for small closed depressions. They occur on various substrates and can have a natural or anthropogenic genesis. In general, mardels on the Strassen marls are abandoned quarries, related to historical clay extraction, and mardels on the Luxembourger sandstone are sinkholes, related to joint patterns. Probably, most of the mardels on the Keuper marls are also abandoned quarries but some of them have a natural genesis as subsidence basins related to subsurface dissolutions of gypsum lenses, present in the marl deposits. During the Late Holocene the mardels became filled with colluvial deposits. The pollen records documented in these deposits can be correlated to Subatlantic climatic oscillations and correspond to changes in the rate of soil erosion and land management. In particular, the Little Ice Age stands out as a period with increased denudation and temporary extension of arable land.

1. Introduction

The present geomorphology of the landscapes in the Devonian Oesling and the Mesozoic Gutland (Fig. 1) is inherited from Tertiary and Quaternary landscape evolution, which was initiated by the Pliocene tectonic uplift of the entire region Luxembourg. The uplift was more pronounced in the Oesling than in the Gutland. As a result the Mesozoic sedimentary rock formations have been completely eroded in the north and the Oesling landscape is now characterized by wide open plateaus developed on Devonian formations, with an average elevation of 450 m, dissected by valleys. The present Gutland is a cuesta landscape, underlain by alternating tilted sedimentary rock formations with different resistance to weathering and erosion.

During the Pleistocene the landscape has been subjected to several cycles of weathering and erosion by the alternation of glacial and interglacial periods (Lucius, 1948; Verhoef, 1966). During glacial periods landscape development was dominated by erosion and denudation under periglacial conditions. During interglacial periods, the landscape became vegetated, denudation was reduced and soil profiles could develop. Relicts of Pleistocene landforms and deposits are scarce in the present landscape. Verhoef (1966) has described some fossil ice wedges and traces of periglacial cryoturbation and ascribed asymmetrical valley development to periglacial conditions.

The Holocene landscape evolution started in a landscape with thin regolithic slope covers and Pre-Holocene gravelly deposits on the valley floors (Heuertz and Heyart, 1964; Verhoef, 1966). Plant growth, rock weathering and soil formation were the dominant processes in the Early Holocene (Slotboom and van Mourik, 2015).

Typically for the geomorphology of the Luxembourger Gutland plateau is the occurrence of mardels, which can be defined as small closed depressions (CDs). Mardels occur on various substrates, in particular on Lias and Keuper formations and may have different genesis. In these CDs, ponds and wetlands developed which potentially contribute to the geodiversity and biodiversity of the landscape. Peat and colluvium, deposited in mardels, are important soil archives for palynological reconstruction of the Late Holocene landscape evolution.

Lucius (1941, 1948) ascribed the mardels, occurring on the Steinmergelkeuper and the Pseudomorphosenkeuper to the subsurface solution of calcareous or gypsum inclusions in the marl formations, followed by collapse and subsidence of the overlying beds. Lucius (1941, 1948) also postulated that mardels can be formed by subsidence as a reaction on tectonic stress, causing joints in the Luxembourger sandstone.

Slotboom (1963) investigated 108 mardels in the Gutland. Based on his field observations he confirmed the genetic conclusion of Lucius.

Braque (1966) suggested that the observed CDs at the plateau of Nivernais (France) developed under periglacial conditions during the Late-Glacial and by karst processes during the Holocene.

Barth (1996) investigated mardels in Lorraine (France). Based on soil descriptions she confirmed the natural evolution of mardels in "Lorraine Gypsiferous Keuper" and rejected anthropogenic geneses. Also she postulated that the formation of mardels is still ongoing in the present landscape.

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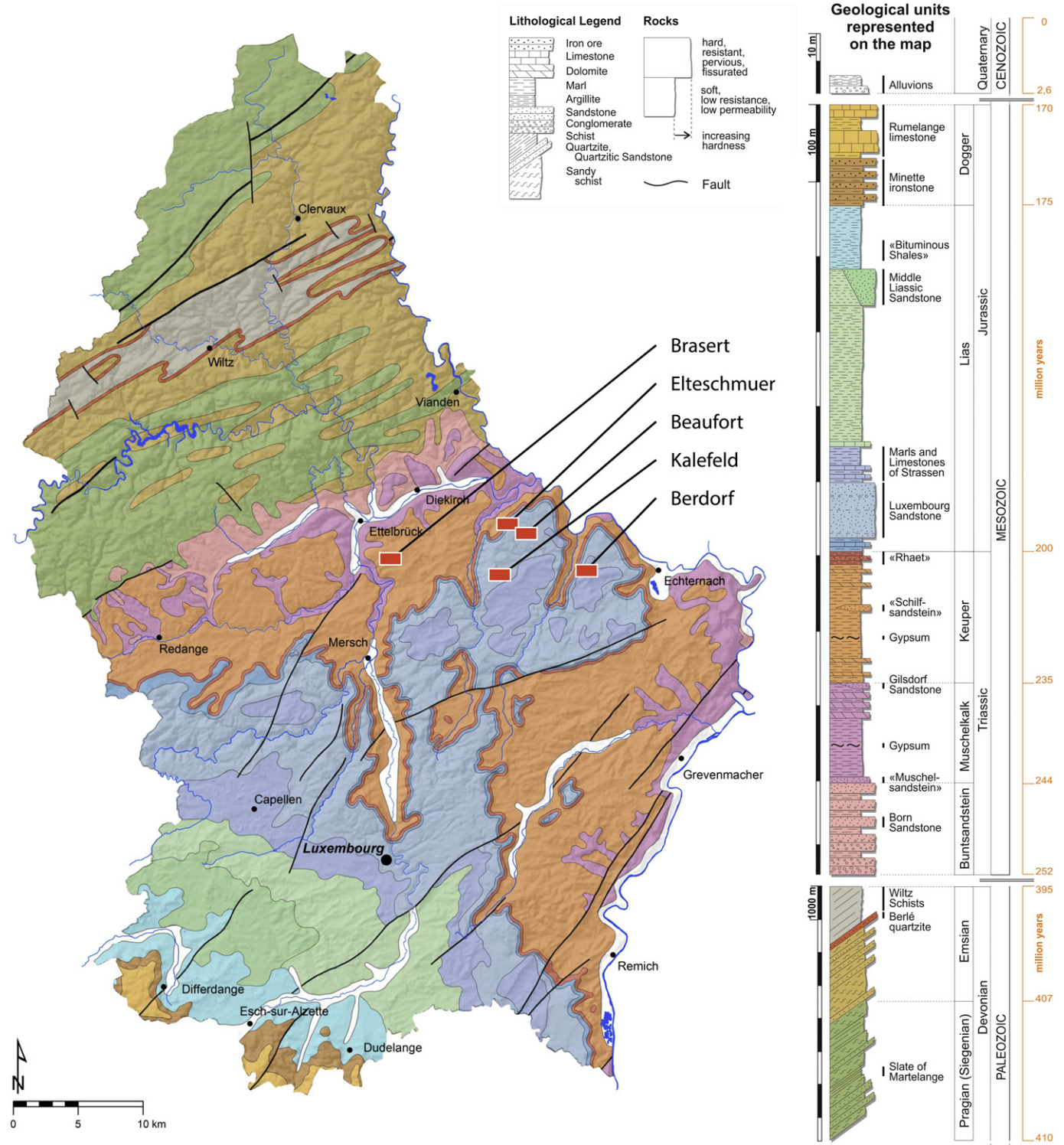

Fig. 1. Geological map of Luxembourg with the sample locations.
Source: Service Géologique de Luxembourg.

Thoen and Hérault (2006) investigated the development of CDs in forests in Lorraine. They suggested the Holocene subsurface solution of evaporitic lenses of haliet, gypsum and carbonate as the major process to explain the development of the CDs. They observed a range of depressions from mature to juvenile and concluded that the development of mardels is still going on.

Vanwalleghem et al. (2006) considered CDs in the Belgium loess belt as anthropogenic landforms. The main function of such CDs was watering places for cattle and excavations of calcareous loess as fertilizer for acid arable land and pasture. In contrast to the geological structures in the Gutland and Lorraine, subsurface evaporitic rock lenses are absent in the Belgium loess belt.

Schmalen (2002) described the occurrence of mardels in the Gutland, Luxemburg. She reported possibilities for natural and anthropogenic genesis of the mardels, but this research focused on water quality and wetland species in these unique biotopes.