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CARBON ISOTOPIC COMPOSITION OF ORDOVICIAN CARBONATES IN BALTO-SCANDIA: SHALLOW MARINE FACIES SHIFTING THE $\delta^{13}\text{C}_{\text{carb}}$ VALUES IN DIFFERENT WAYS

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Secular trends in $\delta^{13}\text{C}_{\text{carb}}$ are mainly interpreted as changes in the global carbon cycle and principal processes of sequestration with straightforward implications to stratigraphy and palaeoclimatology. However, studies on several recent carbonate environments have described and explained cases where carbon isotopic composition of carbonates differ along onshore-offshore profile (e.g., Swart, 2015). This has led to discussion if secular $\delta^{13}\text{C}_{\text{carb}}$ changes in geological sections have been caused or influenced by changes in depositional settings and/or early diagenetic environment.

The facies (aquafacies) differences reflected in $\delta^{13}\text{C}_{\text{carb}}$ bulk-rock values in Ordovician carbonate basins have been recorded in some previous studies from North America (Holmden et al., 1998; Panchuk et al., 2006; Saltzman & Edwards, 2017). Similar depletion trend in $\delta^{13}\text{C}_{\text{carb}}$ values towards the shallower facies has been supposed for the Baltoscandian Basin by Saltzman & Edwards (2017) and Lindskog et al. (2019). These trends have been interpreted as an influence of local input of isotopically light carbon from various sources to the shallow restricted platform, including oxidation of organic matter in land or in water (Saltzman & Edwards, 2017). However, Brenchley et al. (2003) documented the opposite change – increasing $\delta^{13}\text{C}_{\text{carb}}$ values towards the proximal facies in the Hirnantian carbonates of Baltoscandia. Similar landward increasing $\delta^{13}\text{C}$ gradient has been described in Hirnantian interval (HICE) of North America by LaPorte et al. (2009). That was explained by local input of heavy carbon from weathered carbonates, increased photosynthetic activity, and restricted carbon exchange with surface ocean during the low sea level episode (LaPorte et al., 2009).

To map these trends more precisely and explain the different influence of platform facies to the carbon isotopic values we analysed a large $\delta^{13}\text{C}_{\text{carb}}$ dataset from Baltoscandian Middle and Upper Ordovician carbonates. This includes about 40 published and unpublished sections from Estonia, Latvia, NW Russia and Sweden (e.g., Kaljo et al., 2004, 2007; Ainsaar et al. 2010; Lehnert et al., 2014; and others). The sections were correlated using the best available biostratigraphic data and the Baltoscandian carbon isotope-chemostratigraphic correlation standard (Ainsaar et al., 2010), and projected to the global timescale. Ten $\delta^{13}\text{C}_{\text{carb}}$ curves from the deepest central part of the basin, the Livonian tongue, are very similar to each other by isotopic values in all stratigraphic levels and average curve of these sections was taken as composite standard, supposed to reflect the secular changes in the oceanic DIC. The curves of deviation of $\delta^{13}\text{C}_{\text{carb}}$ values from the standard curve were calculated for nearshore areas, compared with sea level changes and sequence stratigraphic units by Dronov et al. (2011).

The $\delta^{13}\text{C}$ curves of Darriwilian and Sandbian interval in northern and central Estonia are shifted about 1‰ and in islands of Saaremaa and Gotland 0.5‰ in negative direction compared to the standard curve of the basin. Still, the deviation of northern Estonian curves is not uniform: the interval of MDICE is shifted 0.7-1‰, whereas the interval of the Kukruse Stage (incl. Upper Kukruse Low) is shifted up to 1.5‰. Sections from NW Estonia with multiple gaps show the depletion of $\delta^{13}\text{C}$ values up to 2‰. There is a weak correlation between the deviation and sea level curve. The transgressive parts of the sequences (e.g., Aseri Stage) are slightly less depleted than late highstand parts or sequence boundaries (Kukruse Stage). The isotopic changes along the facies profile in the Sandbian-Katian transition interval are difficult to analyze. The well-known global GICE is missing in the shallower part of the basin because of a stratigraphic gap and. Other two isotopic excursions, Rakvere and Saunja, are strictly related to the micritic limestone facies and become hardly visible in the condensed sections of the deeper part of the basin. The origin and global correlation potential of these two excursions must be tested by using other geochemical methods.

The $\delta^{13}\text{C}$ curves of upper Katian-Hirnantian interval differ considerably in different facies zones. The $\delta^{13}\text{C}$ values from the interval of the Moe Excursion (BC12 isotopic zone; Ainsaar et al., 2010) are depleted by 0.5‰ in northern Estonia, but increased by 0.3‰ in the sections in Saaremaa island relative to the standard values. The following interval in the middle part of the Pirgu Stage (BC13) shows remarkable $\delta^{13}\text{C}$ depletion exceeding 2‰ both in northern and western Estonia. The uppermost Katian interval, including the Paroveja Excursion is obviously missing in northern Estonia. The HICE interval shows clearly an increasing trend of $\delta^{13}\text{C}$ values towards the nearshore sections. This shift reaches +1‰ in Saaremaa sections and +2‰ in the northern Estonian sections relative to the deeper part of the basin.

The general pattern of changes in $\delta^{13}\text{C}_{\text{carb}}$ values along the facies gradient shows stronger depletion in the marginal areas for the intervals with lower isotopic values in the standard curve, and weaker depletion or increase for the positive carbon isotopic excursion intervals. The weak correlation of the most depleted Darriwilian-Sandbian intervals to sea level lows suggests that depletion of $\delta^{13}\text{C}$ values in shallow marine facies is related to restricted seawater circulation and increased input of lighter carbon isotope during the episodes of lower sea level. This is not the case in Hirnantian interval, where obvious glacioeustatic sea level fall is corresponding to the onshore enrichment of carbonate in heavier carbon isotope. This means that sea level fall and increased restriction of carbonate platform from ocean waters have been led to opposite changes in isotopic composition of carbonate sediments, which might possibly be driven by different magnitude of sea level change or climatic differences. Further studies using different geochemical proxies are needed to fully understand this phenomenon.

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