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Getting salty: A history of the development of elemental salinity proxies for shales

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Salinity is an essential chemical feature of watermasses and routinely reported for modern aqueous systems, but it has been difficult to assess in many paleodepositional systems. Various proxies have been developed for paleosalinity evaluation, including fossil content (e.g., ostracods, dinoflagellates), ichnofossil assemblages, evaporite minerals, stable isotopes (e.g., carbonate O, carbonate Sr, alkenone H), biomarkers (e.g., alkylated chromans, C_{20} isoprenoid thiophenes), and shell elemental content (e.g., Mg/Ca, Sr/Ca, Na/Ca). However, all of these techniques require analysis of specific lithologic, mineralogic, biotic, or molecular components as well as special conditions (i.e., limited diagenesis), limiting their application to paleodepositional systems. Paleosalinity proxies applicable to bulk fine-grained siliciclastics (i.e., shales and mudstones), which comprise ~80 % of total Phanerozoic sediment mass, are needed for the purpose of generating salinity estimates more broadly in deep-time formations.

Certain elemental constituents of shales have the potential to provide paleosalinity information. Historically, the development of elemental salinity proxies can be traced to the 1930's-era studies of V.M. Goldschmidt on the distribution of trace elements in different sedimentary environments. This work inspired a wave of studies in the 1950s and 1960s by noted sedimentologists and geochemists such as Egon Degens, Paul Potter, and Charles Walker, in which various methods based on elemental data were proposed. Although these methods found sporadic application over the past half century, elemental salinity analysis did not become a standard feature of paleoenvironmental studies, for reasons that remain unclear. The last few years have seen a major revival of interest in elemental salinity proxies for shales and mudstones. Wei et al. (2018, IJCG) demonstrated the potential of the B/Ga, Sr/Ba, and S/TOC proxies in an analysis of the Eocene Bohai Bay Basin (Figs. 1 and 2), and Wei and Algeo (2020, GCA) established salinity facies thresholds based on an analysis of modern aqueous and sediment data. These proxies have recently been widely applied to paleodepositional systems as old as the Cryogenian, in nearly all cases revealing strong covariation of salinity with redox and other environmental proxies. The ability to analyze salinity variation in deep-time systems has the potential to generate a renaissance in paleoenvironmental research.

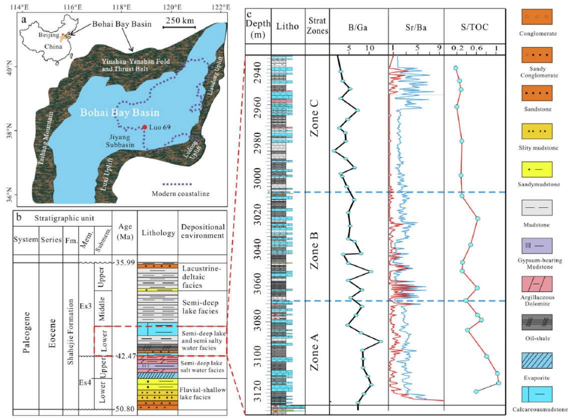

Fig. 1. (a) Geologic map of the Bohai Bay Basin and location of drillcore Luo-69. (b) Stratigraphic column of Shahejie Formation. (c) Chemostratigraphy of study interval, with subdivision into three zones based on lithofacies, fossil content and salinity characteristics.

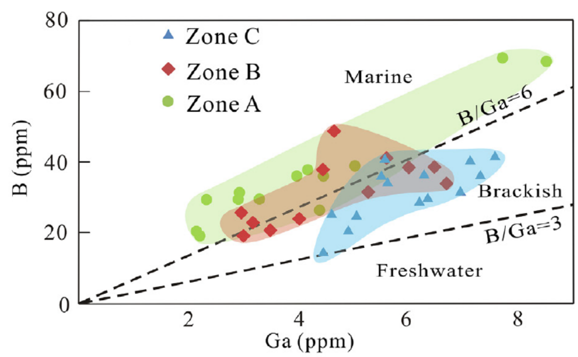

Fig. 2. Crossplot of B vs Ga, with data by zone in the Luo-69 drillcore.