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Recent deposition environments in the Chukchi Sea and adjacent areas of the Arctic Ocean: Evidence from Q-cluster analysis of sediment compositions and grain sizes

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Abstract

Deposition environments in the Chukchi Sea and adjacent areas of the Arctic Ocean are studied by the Q-cluster analysis of compositions, particle sizes, and other properties of surface bottom sediments. Analysis of more than 4700 numeric values allowed mapping fifteen clusters distributed over the seafloor according to deposition environments. Chemical and statistical data confirm the predominance of clastic sedimentation and mainly mechanic sorting of sedimentary material. At the same time, the major-element composition trends correspond to Si decrease and Al increase seaward. Biogenic deposition is of inferior scale and shows up as relative enrichment in total organic carbon, Ca, Mg, Ba, Sr, and some other biogenic and chemogenic components in sediments. Clastic and biogenic deposition, with accumulation of Fe, Mn, V, Ni, Cr, Co, and other elements, as well as precipitation of authigenic phases, occurs within areas of seafloor having particular water chemistry, such as the Herald Canyon, the outer shelf, and the deepwater Arctic Ocean.

Keywords: surface bottom sediments; chemical and grain size compositions; authigenic phases; cluster analysis; clastic and biogenic deposition; redox conditions and diagenesis; Chukchi Sea; East Siberian Sea; Beaufort Sea; Arctic Basin

Introduction

Research in the Arctic Ocean has been progressing recently because the results have important implications for global change and new discoveries of mineral resources exhausted elsewhere and, on the other hand, because advance in science and technology offers new opportunities for this research. A wealth of data on sedimentary sequences including shallow bottom sediments has been gained through active studies in the Arctic region, especially in shelf areas. Enormous volumes of raw data from vast onshore and offshore territories are often processed using cluster analysis which provides fast, compact, and spectacular data presentation. Cluster analysis of major- and trace-element compositions as universal proxies of deposition environments is particularly effective. Surface bottom sediments are in immediate contact with water and are subject to biological and chemical processes. As a natural barrier to upwelling and downwelling flows of material, they store a valuable record of past and present geological settings.

The Chukchi Sea, with its distinctive settings of tectonics, water flow, and sediment transport and accumulation, is one of most interesting Arctic seas, which more so has a high metallogenic potential (Alekseev, 2002; Ivanov et al., 2004; Ivanova et al., 2005).

Deposition environments in the Chukchi Sea: available knowledge

The Chukchi Sea is a shelf basin of the Arctic Ocean located between the Chukchi and Alaska Peninsulas in the Arctic climate zone (Fig. 1). Holocene bottom sediments, from 0.2 m to 5.0 m thick or more (Kosheleva and Yashin, 1999), were deposited at average rates of 15 cm/kyr on the shelf (Shuiskiy and Ogorodnikov, 1981) but at only 1–2 cm/kyr offshore in deep water (Levitan, 2015). Deposition has been maintained by mechanic erosion and processes in the active layer of permafrost (Belov and Ogorodnikov, 1976; Kosheleva and Yashin, 1999; Logvinenko and Ogorodnikov, 1980; Pavlidis et al., 1983; Shuiskiy and Ogorodnikov, 1981; etc.). Sediment transport involves material of different grain sizes and petrographic features (Pavlidis, 1982) unaffected by

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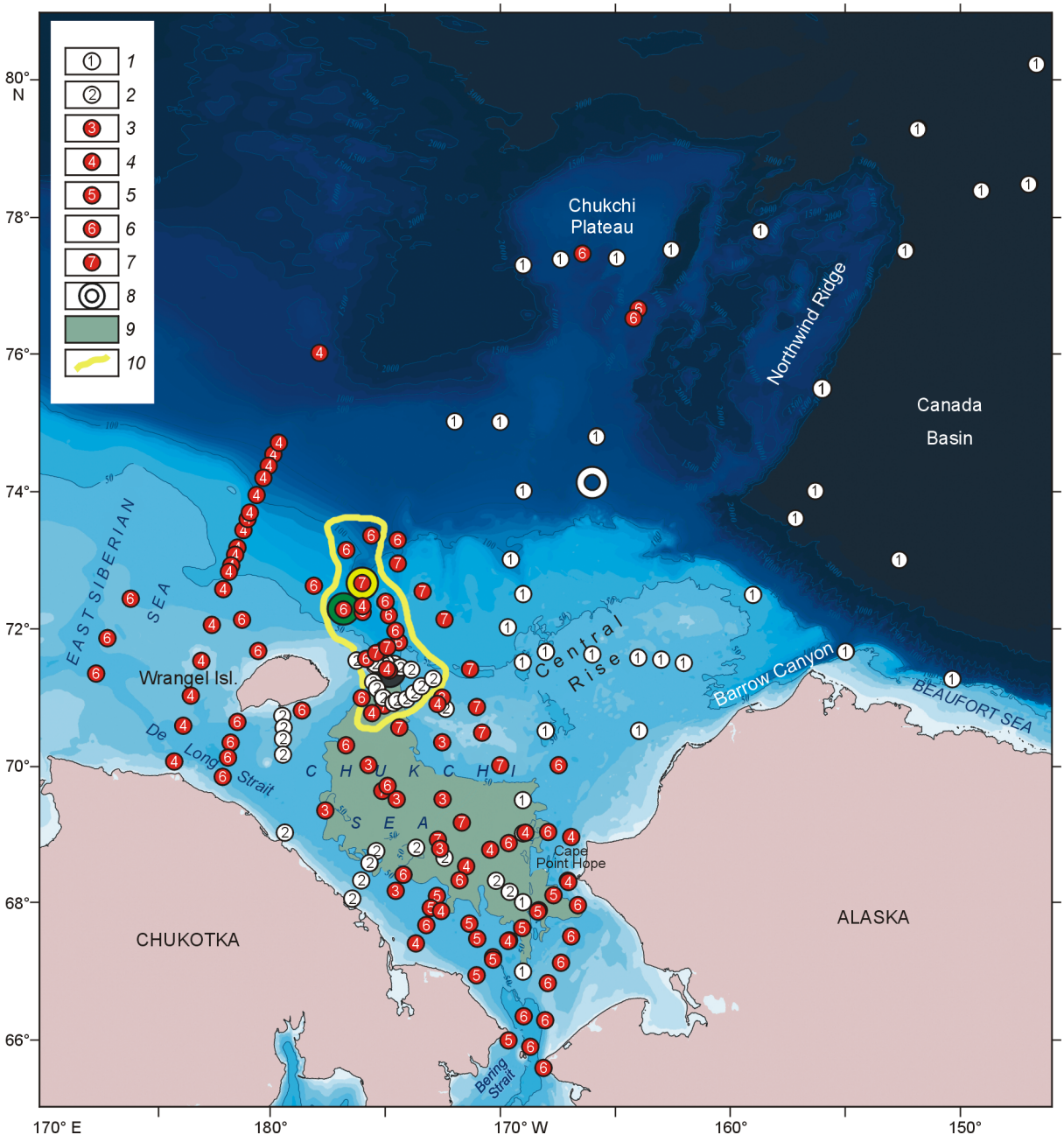

Fig. 1. Map of study area, with sampling sites. *1, 2*, sampling sites for surface bottom sediments, courtesy of people from Tonzhi University, Shanghai (*1*) and VNIIOkeangeologiya, St. Petersburg (*2*); *3–7*, sampling sites for surface bottom sediments collected by people from POI, Vladivostok in different years: R/V *Professor Khromov*, 2002 (*3*), R/V *Professor Khromov*, 2004 (*4*), Hydrographic R/V *Sever*, 2006 (*5*), R/V *Professor Khromov*, 2009 (*6*), R/V *Professor Khromov*, 2012 (*7*); *8*, sites where authigenic precipitates were sampled by people of POI, Vladivostok: green color marks sampling of mainly disc-shaped iron concretions (R/V *Professor Khromov*, 2009); gray color marks sampling of mainly cake-shaped iron concretions (R/V *Professor Khromov*, 2009); white color marks sampling of iron plates and a fragment of a carbonate rock (R/V *Professor Khromov*, 2009); yellow color marks sampling of a single disc-shaped iron concretion (R/V *Professor Khromov*, 2012); *9*, South Chukchi basin; *10*, Herald Canyon.

dissolution and other diagenetic reactions. The basin also receives dissolved compounds, including those of iron and manganese. Most of bottom sediments are of clastic origin and are subject to mechanic sorting. Deposition is strongly controlled by water flow, local erosion of seafloor and islands, submarine topography, and neotectonic activity which bias the existing circum-continental zoning. The greatest part of the shelf (within the 80–100 m water depth contour lines) is a hilly or mainly flat plain slightly dipping to the north, with a few emerged landforms, such as banks of the Central Rise. The banks are remnants of a paleoridge on the extension of the Alaskan Brooks Range (Dobrovolskiy and Zalogin, 1982; Kaplin, 1971; Pavlidis, 1982; etc.). In the southern and western parts, the plain is cut by rifts buried under sediments (Shipilov et al., 1989). The best known Chukchi rift graben extends from the eastern Chukchi Peninsula through the Herald