RELATIONSHIPS BETWEEN COMPOSITION OF ORGANIC MATTER, DEPOSITIONAL ENVIRONMENTS, AND SEA-LEVEL CHANGES IN BACKARC BASINS, CENTRAL JAPAN

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ABSTRACT: **Sedimentary organic matter is a potential indicator of paleoenvironments. In this study we examine the relationship among composition of kerogen (insoluble organic matter), sedimentary environments, and sea-level changes in Miocene to Pleistocene sediments of the Niigata and Akita backarc basins, central Japan. Our primary analytical tool is a ternary diagram with apexes consisting of woody–coaly organic matter, herbaceous with pollen and spores, and amorphous organic matter (AOM) with alginite (organic-walled marine microfossils). The composition of kerogen plots into distinct regions on the ternary diagram: fluvial to estuarine, prodeltaic, shelf, slope and basin-floor submarine fans, and distal basin-floor sediments. The fluvial and estuarine sediments have high proportions of woody–coaly and herbaceous organic matter with pollen and spores, and a lesser proportion of AOM + alginite, because pollen and spores were mainly deposited in estuaries. Because abundant coarse-grained, terrigenous organic matter was supplied by delta distributaries, the prodeltaic sediments have high proportions of woody–coaly organic matter. The composition of kerogen in the shelf sediments is similar to the kerogen in slope and basin-floor submarine-fan sediments, as plotted on the ternary diagram. Both kinds of kerogen accumulations have high proportions of woody–coaly organic matter and AOM with alginite and lesser proportions of herbaceous organic matter with pollen and spores. This relationship suggests that turbidity currents supplied the terrigenous sediments. The sediments on the distal basin-floor contain high proportions of AOM.**

Each pattern in the ternary diagram reflects a difference in hydrodynamic behavior, distance from land, and the supply of terrigenous organic matter. The sub-ternary diagram, which has apexes of WFA (weakly fluorescent amorphous organic matter), NFA (nonfluorescent amorphous organic matter) + FA (fluorescent amorphous organic matter), and alginite, further suggests the origin of AOM. The NFA in shelf sediments and WFA in distal basin-floor sediments are inferred to consist of terrestrial higher plant and marine organic matter, respectively. A $\delta^{13}C$ value of kerogen rich in NFA (−24.6 and −27.3‰) suggests land plants, whereas kerogen rich in WFA (−20.0 to −23.6‰) suggests marine plankton. These inferences agree with those derived from the sub-ternary diagram. Furthermore, compositional changes of the kerogen in turbidites reflect relative sea-level changes, as seen by shifts in compositions on the ternary diagram. The use of ternary diagrams like those used here is recommended for future studies of kerogen, depositional environment, and sea-level relationship.

INTRODUCTION

Organic petrography has been used to recognize the petroleum potential of source rocks and to interpret sedimentary environment, because kerogen (insoluble organic matter) can be obtained from almost all sedimentary rocks. Previous workers have established that the composition of kerogen varies along with siliciclastic environment (Bustin 1988; Parry 1981; Watanabe and Akiyama 1998), and similar studies have been done for carbonate sediments (Gorin and Steffen 1991; Steffen and Gorin 1993; Bombardire and Gorin 1998; Wood and Gorin 1998). The distribution pattern of organic matter is also thought to be controlled by relative sea-level changes. Examples include the Neogene and Quaternary clinoform deposits on the continental margin of North America (Pasley et al. 1991), Upper Jurassic sediments in Tethys (Pittet and Gorin 1997), and Devonian and Carboniferous sediments in southeast Wales (Davies et al. 1991). Paleodepth and paleosalinity are recognized as additional controls on kerogen occurrence (Sato 1980; Ujiié 1992; Ujiié and Jingu 1992). All of these earlier studies suggested that the kerogen modal composition of marine mudstone differs according to depositional setting. Such differentiation should be apparent in a ternary diagram. Shimazaki (1986), in fact, proposed a ternary diagram for the composition of kerogen, but unfortunately it does not reflect sedimentary environments, because kerogen composition was plotted according to stratigraphic position. Parry (1981) also proposed a ternary diagram for the modal composition of kerogen, but the distribution of kerogen composition in their diagram does not agree well with the environmental subdivisions of a delta system. This discordance may stem from the fact that sedimentary environments could be approximated by Parry (1981) from slabs and geophysical logs.

The purpose of this study is to present ternary diagrams that clearly express the relationship between sedimentary environments and the composition of kerogen. Detailed sedimentary environments, depositional systems, and depositional sequences in our study area have been delineated in previous studies (Takano 1998, 2002; Hoyanagi et al. 2000; Omura 2000). We show that the factors that control the composition of kerogen in each sedimentary environment, including the origin and deposition of organic matter and relative sea-level changes, can be deciphered in these ternary diagrams.

GEOLOGICAL SETTING

The Niigata and Akita sedimentary basins are located on the eastern margin of the Japan Sea and are considered to be backarc basins (Fig. 1). The Niigata sedimentary basin is filled with Miocene volcanics and Miocene to Pleistocene siliciclastics more than 5,000 m thick, and evidently formed in close connection with the opening of the Japan Sea (Tamaki et al. 1992). Folded Tertiary strata in the Niigata backarc basin have NNE–SSW and NE–SW-trending axes. Oil and gas are produced from these Neogene rocks, so many detailed geological studies have been undertaken for petroleum exploration (Kageyama and Suzuki 1974; Watanabe 1976; Maiya 1978; Tsuda 1978; Sato et al. 1987; Suzuki 1989; Kobayashi and Tateishi 1992; Kurokawa 1999).

Facies and depositional-system analyses have shown that the Niigata sedimentary basin was filled under a range of environmental conditions: basin floor, submarine-fan, slope, shelf, deltaic, estuarine, and fluvial systems (Fig. 2; e.g., Takano 2002). The Akita sedimentary basin, also situated on the eastern margin of the Japan Sea, is similar to the Niigata backarc basin and has also been studied extensively for petroleum resources (Sato et al. 1988a, 1988b; Matoba et al. 1990; Shiraishi and Matoba 1992).

Sequence stratigraphic studies have been carried out for the upper Miocene and Pleistocene sediments in the Niigata backarc basin. The third-order depositional sequences in the late Miocene strata, which consist of submarine-fan turbidites, exhibit a vertical stacking pattern, whereas those in the Pliocene to Pleistocene strata consist mainly of deltaic sediments with a progradational stacking pattern (Takano 2002).

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