Chemie der Erde 72 (2012) 345–362

Contents lists available at SciVerse ScienceDirect

Chemie der Erde

journal homepage: www.elsevier.de/chemer

Geochemistry of beach sands along the western Gulf of Mexico, Mexico: Implication for provenance

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ARTICLE INFO

Article history:
Received 10 February 2012
Accepted 21 July 2012

Keywords:
Major elements
Trace elements
Rare earth elements
Petrography
Magnetite
Provenance
Passive continental-margin
Longshore current

ABSTRACT

This paper contributes to understanding the intractable problems in provenance study due to hydraulic sorting and geochemical heterogeneity in medium, fine, and very fine sands. For this purpose, detrital modes, major, trace, and rare earth element (REE) compositions of recent sands from the Playa Azul, Tecolutla, and Nautla beach areas of the western Gulf of Mexico have been investigated. Marked geochemical and petrographic differences occur among the three beach sands, even though they are separated just by 45 km. The average quartz-feldspar-lithic fragment (QtFL) ratios for the Playa Azul, Tecolutla, and Nautla sands are respectively $Qt_{69}–F_{10}–L_{21}$, $Qt_{57}–F_{11}–L_{32}$, and $Qt_{37}–F_5–L_{58}$. The volcanic lithic fragment (Lv) – sedimentary lithic fragment (Ls) – [plutonic lithic (Lp) + metamorphic lithic fragments (Lm)] ternary diagram indicates that the Nautla sands are dominated by volcanic detritus, while the Tecolutla sands are dominated by sedimentary and volcanic detritus. The Playa Azul sands are dominated largely by sedimentary detritus. Geochemically, the three beach sands are quite distinctive from each other. The Playa Azul sands are higher in SiO_2 content (~64–84 wt.%) than in the Tecolutla sands (SiO_2 = ~47–69 wt.%). The Nautla sands are very low in SiO_2 content (<46 wt.%). The contrasting geochemical compositions among the three beach areas are also confirmed by significant variations in Al_2O_3/TiO_2, Na_2O/K_2O, K_2O/Al_2O_3, Rb/Al_2O_3, and Cr/Ni ratios. The CIA values (~39–69; chemical index of alteration) for the three beach areas suggest low to moderate weathering nature.

In the three beach sands studied, the decrease in grain size is accompanied by a gradual decrease in SiO_2 content and an increase in TiO_2, Al_2O_3, Fe_2O_3, MgO, Zr, Hf, Cr, and V contents. Similarly, the $\sum$REE content increases with decreasing grain size. However, very fine sands in the Playa Azul and Nautla beaches are different in $\sum$REE content. This observation suggests that the provenance is more important in controlling the geochemical composition of beach sands than the grain size. The zirconium concentration in beach sands, however, is not related to the grain size.

The comparison of REE patterns of beach sands with those of source rocks located relatively close to the study areas suggests that the Playa Azul sands were derived from felsic rocks, whereas a mixed provenance with contributions from felsic and intermediate rocks is more likely for the Tecolutla sands. In contrast, the REE distribution patterns of Nautla sands resemble those derived from basalt and basaltic andesite. However, selective concentration of magnetite grains in beach sands increases the LREE content and fractionates Eu resulting in a europium anomaly that is more negative than that displayed by Nautla sands. All of the above observations suggest that rivers delivering sands to the beaches are the important factors in controlling the composition of beach sands and that longshore currents play a less significant role.

1. Introduction

The geochemistry of clastic sediments has been useful for determining the composition of source areas (Cullers, 2000, 2002; Osae et al., 2006; Armstrong-Altrin, 2009; Saha et al., 2010),

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http://dx.doi.org/10.1016/j.chemer.2012.07.003

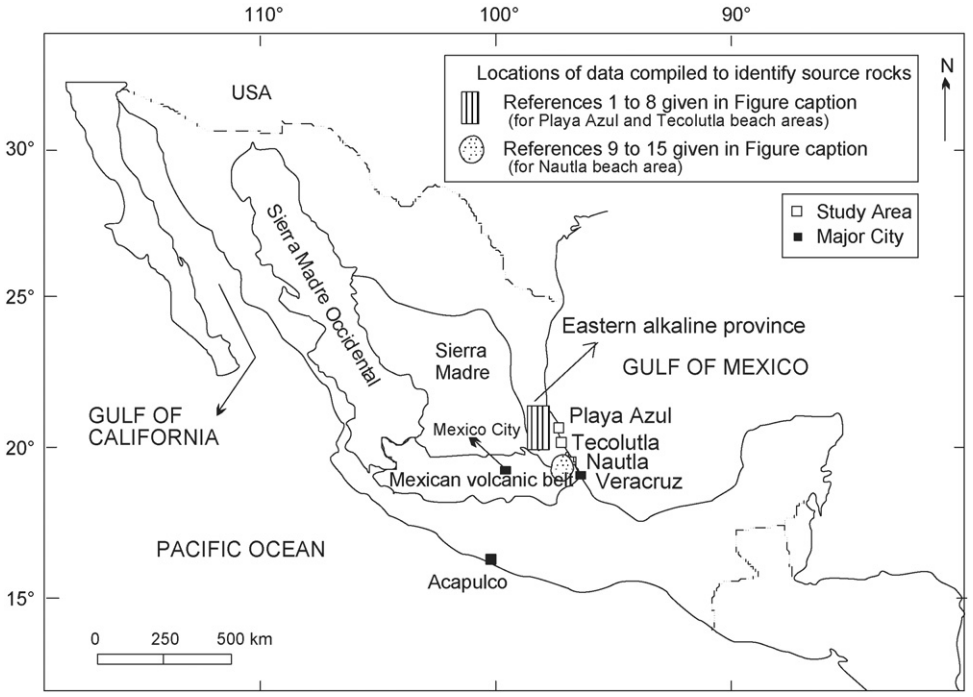

Fig. 1. Map showing study areas and locations of the source areas from where the geochemical data are compiled in this study to identify probable source rocks (map modified after Keppie, 2004). The data sources for provenance of Playa Azul and Tecolutla are: (1) Rosales-Lagarde et al. (2005), (2) Verma (2001a), (3) Verma (2001b), (4) Verma (2000), (5) Orozco-Esquivel et al. (2007), (6) Aguirre-Díaz and López-Martínez (2009), (7) Verma (2003), (8) Verma (2001c); Nautla: (9) Ferriz and Mahood (1987), (10) Carrasco-Núñez et al. (2010), (11) Gómez-Tuena et al. (2003), (12) Orozco-Esquivel et al. (2007), (13) Siebert and Carrasco-Núñez (2002), (14) Carrasco-Núñez et al. (2005), (15) Schaaf and Carrasco-Núñez (2010). The rock types compiled to identify the provenance of Playa Azul and Tecolutla are: dacite (Verma, 2000, 2001c, 2003; Aguirre-Díaz and López-Martínez, 2009; Ferriz and Mahood, 1987; number of samples (n) = 7), andesite (Rosales-Lagarde et al., 2005; Verma, 2000, 2001c, 2003; Ferriz and Mahood, 1987; n = 24), basaltic andesite (Verma, 2001a,b,c, 2003; Ferriz and Mahood, 1987; Orozco-Esquivel et al., 2007; n = 16), Basalt (Verma, 2000, 2001a,b,c, 2003; Orozco-Esquivel et al., 2007; Ferriz and Mahood, 1987; n = 33); Nautla: basaltic andesite (Orozco-Esquivel et al., 2007; Siebert and Carrasco-Núñez, 2002; Carrasco-Núñez et al., 2005; Schaaf and Carrasco-Núñez, 2010; n = 16), and basalt (Gómez-Tuena et al., 2003; Orozco-Esquivel et al., 2007; Siebert and Carrasco-Núñez, 2002; Carrasco-Núñez et al., 2005; Schaaf and Carrasco-Núñez, 2010; n = 61).

the characteristics of chemical weathering in the source region (Selvaraj and Chen, 2006; Roy et al., 2008; Gallala et al., 2009), and reconstruction of the tectonic setting of sedimentary basins (Armstrong-Altrin and Verma, 2005; Sabaou et al., 2009). However, the geochemical composition of sediments depends on other factors such as sorting, diagenesis, and relief. The geochemical variations produced by these factors have been studied by Weltje (2006), Ohta (2004), Lee (2009), and Dostal and Keppie (2009).

The provenance characteristics of beach sands along the Gulf of Mexico have been studied by Self (1975, 1977), Carranza-Edwards and Rosales-Hoz (1995), Okazaki et al. (2001), Kasper-Zubillaga and Dickinson (2001), and Carranza-Edwards et al. (2001). Kasper-Zubillaga et al. (1999) interpreted that the composition of beach sands of the Gulf of Mexico to be associated with specific source rocks, and therefore potentially useful in identifying the tectonic setting of a sedimentary basin. Recent work by Armstrong-Altrin (2009) revealed that the beach sands of the Cazones, Gulf of Mexico are composed mostly of detrital components derived from felsic source rock (75% rhyolite and 25% andesite). However, both of these studies were based on sand samples collected from a single beach and within a restricted geographic area. In this study, the modal composition and geochemical characteristics of sands collected from beaches at Playa Azul, Tecolutla, and Nautla in the western Gulf of Mexico were determined (Figs. 1 and 2). The distribution of sediments along these three beach areas are largely controlled by the influence of sediments derived from the Cazones, Tecolutla, and Nautla rivers, respectively. Moreover, beach sands in each of these coastal areas receive sediments from different source areas. The aims of this study are (1) to characterize the geochemical variations among the three beach areas (2) to infer the role played by the accessory minerals on the geochemistry, and (3) to explore how source rock compositions may affect provenance interpretations.

2. Study area

The Playa Azul (20°42′06.41″N and 97°11′41.13″W), Tecolutla (20°27′28.88″N and 96°59′04.13″W), and Nautla (20°13′15.56″N and 96°46′04.12″W) beaches are located in the western part of the Gulf of Mexico (Figs. 1 and 2). The Tecolutla beach is located between the Playa Azul and Nautla beaches. The coastal plain is narrow in the middle of the Tecolutla beach and is wider towards the north and south. The climate is tropical to temperate with rainfall and temperature dependent on elevation (Tamayo, 1991). The annual rainfall averages 1500 mm over the entire area, with a distinct rainy season occurring in August and September (Self, 1975).

The coast is classified as transgressive and wave-dominated (cf., Boyd et al., 1992) and the geology of the coastal area is diverse (Carranza-Edwards and Rosales-Hoz, 1995), and the outcrops along the western Gulf of Mexico is composed of (1) Quaternary alluvium and soils, (2) Cenozoic volcanic rocks of mafic and intermediate composition, (3) Cenozoic and Mesozoic clastic and calcareous sedimentary rocks, and (4) metamorphic rocks comprising schists and gneisses of Paleozoic and Precambrian age (Padilla-Sanchez and Aceves-Quesada, 1990).

The rivers feeding sediment to the beaches at Playa Azul, Tecolutla, and Nautla are the Cazones, Tecolutla, and Nautla rivers, respectively (Fig. 2). The Tecolutla and Cazones rivers probably carry sediment richer in sedimentary rock fragments and less rich in volcanic rock fragments than the Nautla River since their drainage basins are dominated by sedimentary exposures.