



# Isotope geochemistry of the Miocene and Quaternary carbonate rocks in Rabigh area, Red Sea coast, Saudi Arabia



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## ABSTRACT

The Rabigh area, a coastal region north of Jeddah city, Saudi Arabia contains raised Quaternary coral reefal terraces and reworked coral fragments mixed with sand and gravel. This area has a thin exposure Lower Miocene shallow marine carbonate rocks that laterally pass into evaporites. The Miocene carbonate and evaporite rocks conformably overly the Lower Miocene siliciclastic sequence, are in turn capped by the Harrat basaltic boulders. The Miocene carbonates are made up of dolomitic packstone, wackestone and mudstone, whereas the overlying Quaternary reefal terraces are composed of coral boundstone and grainstones.

The Quaternary reefal terraces of Rabigh area have been dated using the uranium-series dating method to obtain precise dates for these corals. The calculated ages (128, 212 and 235 ka) indicate that deposition took place during high sea level stands associated with interglacial times during Oxygen Isotope Stages (OIS) 5 and 7. The youngest age (128 ka) clearly corresponds to stage 5e of the last interglacial period. The obtained ages correlate well with those of the emerged reefs on the Sudanese and Egyptian coasts at the western side of the Red Sea. The broad distribution of wet climate, pluvial deposits on the continents and high sea level stands indicate a wide geographical range of the interglacial events of the Oxygen Isotope Stages (OIS) 5 and 7.

The oxygen and carbon isotopic composition of the Miocene and Quaternary carbonate rocks in Rabigh area show a broad range of  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$ . The Quaternary carbonate rocks have significantly higher  $\delta^{13}\text{C}$  than the Miocene ones, but low  $\delta^{13}\text{C}$  values of the Miocene samples likely indicate a high contribution of carbon from organic sources at the time of deposition. Linear trends are evident in both groups of samples supporting the likelihood of secondary alteration.

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## 1. Introduction

The Neogene successions in the Red Sea coastal plain of Saudi Arabia display a great lithological diversity, composed of discontinuous sequences of carbonates, evaporites and mixed carbonate and siliciclastics (Hughes and Johnson, 2005). The Miocene carbonate and evaporite rocks have been studied in the Rabigh area (Fig. 1) particularly with respect to sedimentology, diagenesis, depositional environments, stratigraphy and paleontology by Mandurah (2010), Mandurah and Aref (2010, 2012), Aref and Mandurah (2011), Aref and Taj (2012), and Taj (2012, 2013). Whereas the

Miocene siliciclastic rocks were the interest of Gheith and Abou Ouf (1997), Abou Ouf (1998), Taj et al. (2002), Basyoni et al. (2002), and Ghandour and Al-Washmi (2013). The Pleistocene coastal sediments were the interest of Behairy and El-Sayed (1984), Durgaprasada Rao et al. (1987), Basaham (1998, 2004), Bantan (2006), Mandurah (2009), and Ghandour and Al-Washmi (2012).

The age dating of the Quaternary coral reefal terraces were the interest of other authors. Behairy (1983) found three prominent marine cut terraces between Jeddah and Yanbu that lie 1, 3 and 10 m above the present sea level.  $^{14}\text{C}$ -dating of coral limestone samples by Behairy (1983) revealed four marine transgressions took place on the west coast of Saudi Arabia between the mid-Pleistocene to present. These sea level maxima are reported at about 31, 16.6–18.1, 9.98 ka BP and (Mid-Pleistocene?). Jado and Zotl (1984) recognized that marine and terrestrial terraces along

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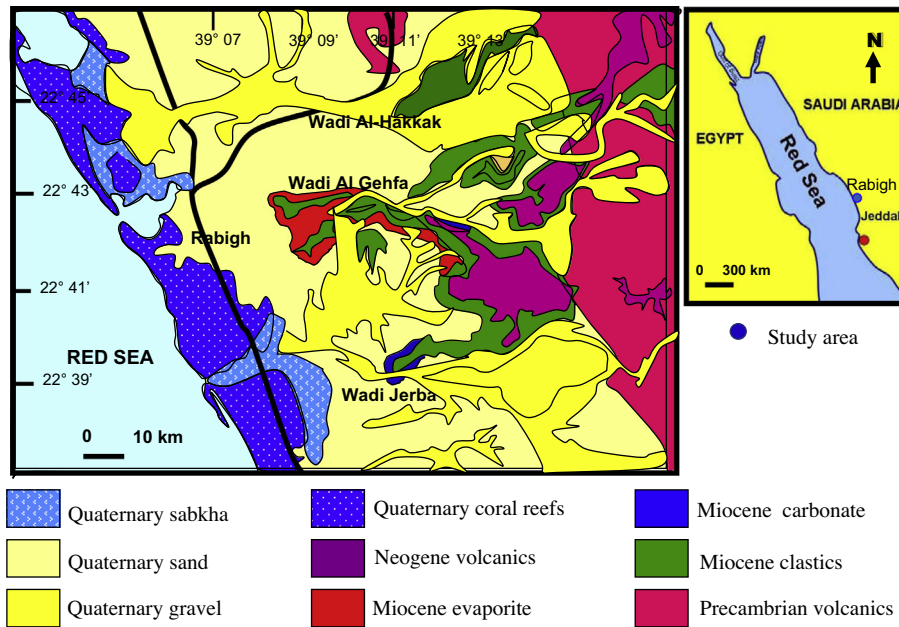


Fig. 1. Geologic map of Rabigh area, Saudi Arabia (modified after Ramsey, 1986).

the Red Sea coast of Saudi Arabia, overlie Pliocene sediments unconformably and were formed mainly by eustatic sea level changes and subordinately by vertical tectonics. The most recent terraces are described by Jado and Zotl (1984) between 6 and 10 m above present sea level and represent the last interglacial high sea levels, as dated by uranium/thorium at about 9.5–120 ka BP.

Because the  $^{14}\text{C}$ -dating method is limited to samples less than 50 ka BP, and the dating range of U-series method extends to 350 ka BP, the studied Quaternary reefal terraces could be dated by using the latter technique. The purpose of the present work is to date the Quaternary reefal terraces using  $^{230}\text{Th}/^{234}\text{U}$  dating method, and to investigate the carbon and oxygen isotopic composition of the various Miocene and Quaternary carbonate rocks in Rabigh area, north Jeddah city (Fig. 1).

## 2. Methodology

Analyses of three selected Quaternary carbonate rock samples from the raised reefal terraces at Rabigh area have been done in the radio-isotope laboratory of the Faculty of Engineering, King Abdulaziz University. The uranium and thorium isotope analyses are carried out as described in detail by Lally (1992). The whole-rock samples were pulverized to 200-mesh size by ball milling. About 3 g were dissolved using a warm mixture of HCl and  $\text{HNO}_3$ , and later the sample was filtered.  $^{232}\text{U}$  and  $^{229}\text{Th}$  spike tracers were added to the samples before digestion. After dissolution, the samples were left for three days to reach isotopic equilibrium. A carrier consisting of ferric nitrate was added, then the sample was heated to boiling and the pH increased to a value of about 10 by the addition of ammonium hydroxide. The actinides including uranium and thorium co-precipitate with a ferric hydroxide floc. After separation of the floc by centrifugation, the iron was separated from the actinides by solvent extraction with diethyl ether. The anion exchange procedures were performed for U–Th separation and purification. The resin used is Bio-Rad AG 1 $\times$ 8, 100–200 mesh; in a chloride form. Both hydrochloric and nitric acid stages of anion exchange were used. Thin sources of purified uranium and thorium fractions were prepared by electrodeposition onto

stainless steel discs for subsequent isotope measurements by alpha spectrometry. The uncertainty of the measurements was calculated using standard error formulae based on counting statistics (Friedlander and Kennedy, 1956). The ages based on the uncertainties were calculated as described by Ludwig and Titterton (1994) and by using isoplot software.

At the same time, fifteen carbonate rock samples were analyzed for their O and C isotope values at the laboratory of Saudi Aramco. In this technique, the rock powder, stored in sealed screw-cap glass vials, was obtained by drilling out small portions of the hand specimens with a power drill and a 1/8" or 1/4" masonry bit. In one instance, sub-samples having similar fabric were taken to evaluate isotopic heterogeneity of the sample. 0.2–0.4 mg of rock powder was loaded in 12 ml Exetainer screw cap vials and the headspace flushed with ultra pure helium at 130 ml/min for 8 min to remove air. Four drops (about 0.08 ml) 100.5%  $\text{H}_3\text{PO}_4$  were added to each vial with a hypodermic syringe and the samples allowed to react for 2 h at 62 °C. Helium flushing and headspace  $\text{CO}_2$  analysis was carried out automatically with a Thermo Fisher Gas Bench preparative device interfaced to a Delta Plus XP stable isotope mass spectrometer. Isotope ratios were corrected for variations in peak intensity using house carbonate standards ("Calcite" and "Merck") calibrated against NBS-19 and Lithium carbonate standard of H. Svec (LSVEC). Aliquots of NBS-18, NBS-19 and LSVEC were run together with the samples. Most analyses were carried out in duplicate.  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  are reported relative to Vienna Pee Dee Belemnite (VPDB). Pooled standard deviations calculated from replicate analyses of standards suggest an overall reproducibility of +0.04‰ and +0.10‰, respectively (14° of freedom). The reproducibility of the values obtained from some samples is poor, suggesting inhomogeneity of the powder due to fine-scale variations in the isotope composition. The percent of  $\text{CaCO}_3$  in the samples, calculated from the response of pure calcite standards, is generally reproducible to +10%.

## 3. Location and geologic setting

The Rabigh area is located along the coast, about 175 km north of Jeddah city (Fig. 1). The outcropping rocks in this area are

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