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Heavy minerals in marine and fluvial sediments: provenance indicators and distributions in the tropical southeastern shelf of the Gulf of Carpentaria and its hinterland North Australia

Rabea A. Haredy

University of Wollongong

HEAVY MINERALS IN MARINE AND FLUVIAL SEDIMENTS: PROVENANCE INDICATORS AND DISTRIBUTIONS IN THE TROPICAL SOUTHEASTERN SHELF OF THE GULF OF CARPENTARIA AND ITS HINTERLAND NORTH AUSTRALIA

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By

Rabea A. Haredy

(MSc-Research, University of Wollongong, Wollongong, Australia)

(BSc, King Abdul Aziz University, Jeddah, Saudi Arabia)

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DEDICATION

To my lovely parents, Abdulkadir and Elham.

To my supervisors.

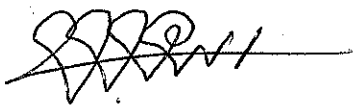
To my brothers and sisters.

To my wife Enas Meeralim.

To any one who was sincere with me.

CERTIFICATION

I, Rabea A. Haredy, declare that this thesis, submitted in fulfillment of the requirements for the award of Doctor of Philosophy, in the School of Earth and Environmental Sciences, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.



Rabea A. Haredy

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ABSTRACT

Provenance and spatial distribution of heavy minerals have been investigated in the tropical southeastern shelf of the Gulf of Carpentaria and its major surrounding river systems, Northern Australia. Heavy mineral assemblages in the very fine sand fraction (63-125μm) of 365 sediment samples were assessed using petrographic and electron microprobe analyses. In addition to opaque minerals, seventeen translucent heavy mineral types were identified in the study area. Zircon, tourmaline hornblende, epidote, sillimanite, rutile and garnet generally represent about 80-100% of the total translucent heavy mineral assemblage.

The chemically variable tourmaline, amphibole, epidote and garnet mineral grains show wide compositional ranges. Tourmaline grains are mostly schorl or dravite, associated with very rare uvite. Amphibole grains mainly consist of calcic-amphibole in the hornblende solid solution series, with very small amounts of actinolite and tremolite. Epidote also shows a wide compositional range, with $Fe^{3+}/(Al+Fe^{3+})$ ratios ranging from 0.01 to 0.49. Garnet is dominated by andradite and almandine associated with minor andradite-grossular, almandine-pyrope, spessartine, pyrope and grossular. The occurrence of several heavy mineral types from the previous mineral groups, together with several morphological population of zircon and other minor and rare heavy minerals including andalusite, staurolite, kyanite, titanite (sphene), chromian spinel, biotite, chlorite and pyroxenes produce complex heavy mineral assemblages in the modern sediments of the southeastern shelf of the Gulf of Carpentaria and its modern fluvial sands, reflecting a mixing of detritus from heterogeneous sources that contain a variety of metamorphic and igneous rocks together with earlier sedimentary successions.

The chemical and petrographic characteristics, as well as spatial distribution and concentration of heavy minerals in the study area, reflect the signatures of the local lithologies in the gulf hinterland, especially the Georgetown Inlier, Mt Isa Inlier and Coen Inlier-Carpentaria Basin divisions. However, the shelf sediments also contain ultrastable heavy minerals (zircon, tourmaline and rutile) that were probably derived from non-local sources by reworking of quartz sand from the northwestern shelf to the southeastern shelf and coastal environments of the gulf during the last marine transgression.

The spatial distribution of heavy minerals in the southeastern shelf of the Gulf of Carpentaria and its surrounding river sediments is mainly influenced by the proximity of heterogeneous provenance areas, the high rate of fluvial supply caused by monsoon cycles, sea level change and hydrodynamic conditions. The spatial variability of heavy minerals forms a total of twelve distinct heavy mineral facies (identified through Q-mode cluster analysis) that characterise the surface and sub-surface sediments of the southeastern shelf of the Gulf of Carpentaria, as well as the fluvial sediments in the gulf hinterland. The shelf surface facies include the surface of the northern submerged coral reef heavy mineral-free facies (SCRHMFF), the heavy mineral facies of the middle part of the southeastern shelf together with the surrounding area of the northern submerged coral reefs (MCRHMF), the Bryomol Reef heavy mineral facies (BRHMF) and the heavy mineral facies of the nearshore area together with the western margin of the middle part of the southeastern shelf (NWMHMF). The shelf sub-surface heavy mineral facies (SSHMF1-6) comprise three facies (SSHMF1-2 and SSHMF5) dominated by terrigenous sediments that reflect the signature of the adjacent sources, two reworked sub-surface heavy mineral facies (SSHMF3-4), and finally the heavy mineral-free SSHMF6 that mainly consists of calcareous marine sediments. The fluvial facies in the hinterland include the heavy mineral sedimentary succession facies (HMSSF) and the heavy mineral metamorphic inlier facies (HMMIF), the latter being divided into three distinct sub-facies (HMMIF1-3).

The main source of terrigenous sediments in the studied shelf area is the fluvial HMMIF that drains the Coen Inlier-Carpentaria Basin, Georgetown Inlier and Mt Isa Inlier divisions, and the mixed source division of the Georgetown-Mt Isa Inliers-Great Australia Basin. This fluvial facies is characterised by high concentrations of metastable minerals, especially epidote and hornblende. The shelfal NWMHMF,

SSHMF1-2 and SSHMF5 reflect the signature of this fluvial HMMIF. These shelfal facies suggest a high terrigenous input and direct filling of the fluvial channels within the southeastern shelf of the Gulf of Carpentaria during Holocene from the adjacent lithologies in the gulf hinterland, especially from the Gilbert, Norman, Flinders and Leichhardt Rivers. Also the shelfal MCRHMF reflects the signature of the fluvial HMMIF, with a significant contribution from the HMMIF1, suggesting reworking of terrigenous sediments by the clockwise tidal circulation pattern from the northeastern nearshore environment.

The heavy mineral assemblages of the shelfal BRHMF and SSHM3-4 are characterised by the highest content of ultrastable heavy minerals, suggesting reworking of marine sediments from the northwestern shelf of the Gulf of Carpentaria during the post-glacial marine transgression that also increased the concentration of ultrastable heavy minerals in the MCRHMF. As a result of the clockwise tidal circulation pattern, the SSHMF3 probably received a mixture of reworked terrigenous sediments from the Archer, Coen and Coleman Rivers that drain the upper Coen Inlier-Carpentaria Basin division (HMMIF1) and the Wenlock River from the HMSSF. However, the BRHMF and SSHMF4 probably contain a mixture of reworked fluvial sediments from the entire HMMIF.

The shelfal SCRHMFF and SSHMF6 are characterised by the absence of heavy minerals. Fine sediments were mainly removed by wave and current action during reef growth over several sea level cycles during the Quaternary. In addition, current strength and even storm conditions would be unable to lift heavy minerals to these elevated situations. As a result of the above processes and the positive relief of the reef surface, no heavy minerals were found in the very fine sand fraction on the reef surfaces.

The strong affinity between the fluvial and shelfal heavy mineral facies is explained by the high rate of fluvial supply caused by monsoonal climate conditions. The expected effects of strong chemical weathering under humid tropical climate conditions over the gulf region are suppressed and diluted by the high rate of monsoonal river runoff that rapidly transports sediments along the rivers into the gulf. Such a mechanism minimises the mineral residence time in the alluvial storage and thus reduces the effects of chemical weathering. Therefore, unstable heavy minerals are preserved together with stable and ultrastable minerals in the assemblages. The overall low feldspar weathering index supports the weathering-limited conditions, whereby the transportation processes are faster than the weathering rate. Also, the short fluvial distances associated with this intense transportation reduce the effects of physical abrasion and thus minimises the loss of unstable minerals. Further, in addition to low chemical weathering caused by monsoonal climate conditions (dry for 8-9 months of the year), the dominance of physical disintegration in this tropical climate reduces the effects of weathering of exposed source rocks in the gulf hinterland. As a result of weathering-limited conditions and short fluvial transport distances, the southeastern shelf of the Gulf of Carpentaria and its hinterland form a set of unique tropical heavy mineral facies that reflect the signature of the local source lithologies.

The relationship between the fluvial and shelfal surface and sub-surface heavy mineral facies identify pathways for marine sediment transport within the southeastern shelf of the Gulf of Carpentaria. Marine transport pathways are mainly controlled by the clockwise tidal circulation patterns within the gulf. In addition, cyclone conditions or large storm events are likely to enhance, but not control, the formation of the heavy mineral facies.

Finally, the light mineral fractions in the study area are mostly quartz-dominated, except for the carbonate reef areas that are composed of shell materials. As a result of the limited differential hydrodynamic properties between the silicate- and carbonate-dominated particles, light mineral fractions in the southeastern shelf of the Gulf of Carpentaria and its hinterland provide poor mineralogical facies recognition. Therefore, heavy minerals are more effective than the light minerals in defining provenance, distribution patterns and transportation pathways in the southeastern shelf of the Gulf of Carpentaria.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES