Six million years of Leeuwin Current history using changes in water column stratification and productivity

*Beth Anne Christensen[1], David DeVleeschouwer[2], Jeroen Groeneveld[2], Benjamin Petrick[3], Lars Reuning[5], Gerald Auer[4], Expedition 356 Shipboard Scientific Party

1. Environmental Studies Program, Adelphi University, 1 South Avenue, Garden City NY, 11530, USA, 2. MARUM–Center for Marine and Environmental Sciences and Department of Geosciences, University of Bremen, 28359 Bremen, Germany, 3. Max-Planck-Institut für Chemie, Mainz, 4. Institute of Earth Sciences, University of Graz, Heinrichstrasse 26, Graz 8010, Austria, 5. EMR –Energy and Mineral Resources Group, Geological Institute, RWTH, Aachen University, Wuellnerstrasse, Aachen 52056, Germany

The Leeuwin Current (LC) is a warm ocean current that flows southwards along the western Australian coast. Changes in the dynamics of this current can have a significant impact on the continental climate in SW Australia. Yet, there is a limited understanding of the timing of the onset of the LC, as well as of its variability. Furthermore, the relationship between LC variability and SW Australian climate is poorly constrained. Expedition 356 drilled a series of sites off the western margin of Australia to evaluate the evolution of the LC. These long, generally continuous records provide the opportunity to reconstruct LC dynamics over the last 6 million years. Moreover, these records provide a unique archive of continental climate change, recorded changing fluxes of wind-blown dust and fluvial transport. Here, we present paleoceanographic and paleoclimate interpretations of oxygen isotopes and scanning XRF from IODP Sites U1459 (28.67°N) and U1460 (27.34°N) off SW Australia.

Previous work on the NW Australian shelf (Site U1463, 18.97°N) revealed a rapid onset of humid conditions at 5.5 Ma, and a transition at 3.3 Ma to the onset of arid conditions and the development of the modern NW dust pathway by 2.4 Ma. The longer- scale changes at Sites 1459 and U1460 are generally in accord with the timing identified for Site U1463. At 5.5 Ma, when Australia becomes more humid as it is surrounded by warmer waters associated with the expansion of the WPWP, the Western Australia Current is dominant off SW Australia. The onset of a proto-Leeuwin Current south of the NW Cape as suggested by indicators for reduced productivity (e.g., Ba/Al) at 4 Ma, is coeval with the restriction of the Indonesian Throughflow (ITF) as the Maritime Continent emerged. Atmospheric conditions may also place a role in the development of the LC. Today, the LC is strongest during Austral winter, when the opposing northward blowing winds are weaker (e.g., Feng et al, 2003). In Austral summer, when the ITCZ straddles Australia, the alongshore pressure gradient and the northward blowing winds are maximum, counterworking the LC. The increase in stratification observed in the mid-Pliocene (~4.0 Ma) suggests an increase in the influence of the LC at Site U1459. Using the modern-day circulation pattern as an analogue, this implies a weaker alongshore pressure gradient during summer, and thus a more northerly position of the ITCZ. At ~3.3 Ma, we observe a short-lived event, likely M2, characterized by cooler surface waters and an increase in productivity. The timing is consistent with the transition interval identified at Site U1463 and indicates a strengthening of the WAC. It is unlikely to be related to reduced trade wind strength associated with a more southerly ICTZ, but instead is attributed to a combination of reduced sea level and continued restriction of the ITF.

Our hypotheses about ocean circulation and productivity should align with the records of terrestrial input. Intervals during which the ITCZ reaches more southerly latitudes during Austral summer were characterized by more summer precipitation, and thus should be associated with higher Fe. Indeed, for the late Pleistocene, Fe seems to be elevated during interglacial periods indicating continental material

was transported offshore by strong trades when the LC was stronger. Conversely, Ni/Cl, a likely productivity indicator, is generally higher during glacial periods, and potentially when the WAC dominates. On a longer timescale, Ni/Cl tracks the natural gamma radiation elemental ratio, U/Th, recording Pleistocene variations in productivity, and Fe inversely covaries, indicating periods with high delivery of continental sediments to the study area.

Feng, M., Meyers, G., Pearce, A. and Wijffels, S. (2003) Annual and interannual variations of the Leeuwin Current at 32°S. Journal of Geophysical Research 108: 3355, doi:10.1029/2002JC001763.

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