LATE NEOGENE AND QUATERNARY TECTONICS AND LANDSCAPE EVOLUTION ALONG THE SOUTHEASTERN AUSTRALIAN PASSIVE MARGIN, CAPE LIPTRAP, AUSTRALIA

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GEOLOGIC SETTING

Lying within the Australian-Indian plate (Fig 1a), the Australian continental margin is often referred to as a classic, passive continental margin, similar to passive margins in southern Africa, India or the Atlantic margin of the eastern United States. Yet, the southern portion of the Australian passive margin displays many topographic, geologic and tectonic attributes that are not typically associated with passive continental margins. These include one of the most spectacular, seaward facing escarpments, the Great Escarpment, with up to 1000 m of local relief along the eastern and southeastern margin; the Australian Highlands (Fig. 1a), elevated topography rising up to nearly 2500 m within 100 km of the coast; active thrust faulting within those mountains that place Paleozoic rocks over Quaternary gravels (cited in Orr, 1998); significant, historic seismic activity that appears to be concentrated along reactivated Cretaceous rift structures (Seismic Research Centre, 2000); and tilted and faulted Neogene to late Quaternary fluvial deposits, marine terraces, and overlying aeolian deposits (Abele, 1988; Jenkins, 1988).

Several hypotheses have been offered to explain theses features including: 1) topography and relief may have developed before Cretaceous rifting (van der Beek and Braun, 1999); 2) some or all of the present relief may be inherited from Late Jurassic-Early Cretaceous rifting (Young and McDougall, 1993, Ollier and Pain, 1994); 3) some of the present relief may have developed (and is continuing to develop) in response to Tertiary isostatic rebound and flexure from denudation and offshore loading (Lamebeck and Stephenson, 1986, Bishop and Brown, 1992) or Tertiary tectonic movements (Orr, 1998); and 4) thermal structure of the crust/mantle (Young, 1989) or far field and intraplate stress (Sandiford, 2002 and in press) may be contributing to (or may be mostly responsible for) the modern relief.

One aspect of the southern Australian coast that must certainly be taken into account in any hypothesis for its geologic evolution and landscape development is the field evidence for continued and active tectonism in the form of offset and deformed Neogene and Quaternary fluvial, marine and aeolian deposits and historic seismicity along mapped fault zones. These Neogene and Quaternary deposits have not been mapped in detail nor has their record been incorporated into existing tectonic or climatic evolution models. Thus, the main purposes of this research are twofold. We undertook detailed mapping and dating of these Neogene to late Quaternary deposits to determine the nature, amounts, rates and spatial distribution of deformation along the southern Australian coast. We also undertook mapping and dating of the extensive aeolian deposits around Cape Liptrap (Figure 1b) in an effort to ascertain the interaction between glacial/interglacial cycles and aeolian activity.

STUDENT PROJECTS

Nine Keck students arrived in Melbourne, Australia on June 17, a blustery winter day. We drove to our field station in Toora, along the coast southeast from Melbourne and settled into the Toora Tourist Park run by Heather and David Bligh. After several days of introductory field trips students selected projects that provided some fundamental answers to our tectonic and climatic questions about the southern Australian margin. The projects fall into two basic groups, those addressing tectonic questions and those addressing climatic questions, with one or two overlapping those topics.

Five students selected projects dealing with marine terraces and related deposits. Two students elected to study the extensive aeolian deposits. One student looked at some odd concretions (we called them "stress pencils" in the field) that are developed in the aeolian deposits near sea level. And one student decided to investigate the anomalous faulting and structural geology of Neogene fluvial units associated with some old placer tin mines.

Aaron Davis, Colorado College, spent his time at Arch Rock studying the Late Pleistocene, calcareous aeolianites that make great sea cliffs and offer spectacular climbing (Fig 1b). He constructed outcrop maps from digital photography, constructing numerous stratigraphic columns, described paleosols, and collected samples for Optically Stimulated Luminescence (OSL) dating. Four OSL ages were produced from his study, ranging in age from 68ka to 89ka. These aeolian deposits probably represent extensive aeolian activity on the exposed continental shelf before, during and immediately after the sea level maxima at Oxygen Isotope Stage 5a.

Elizabeth Cassell, Carleton College, worked on nearby Morgan's Beach (Fig 1b). Those beach cliffs are composed of some intriguing calcareous and siliceous sands that shed light on the Late Pleistocene fluvial history and reworking of aeolian sediments. She constructed numerous stratigraphic columns and collected samples for OSL and radiocarbon dating. Four OSL ages and one radiocarbon age were produced from her investigation. The OSL ages are tightly clustered around 24ka +- 1ka with an underlying peat age of 37, 320 +- 610 yBP. This indicates significant reworking of aeolian sediments during the Last Glacial Maximum (LGM) at around 20ka.

Lindsay McCullough, Wittenberg University, discovered some quite odd-shaped calcareous concretions in the lower portions or the aeolian sediments at Arch Rock and Morgan's Beach. Were they formed by tectonic pumping of groundwater during discrete earthquake events; groundwater flow controlled by sea level over an extended period of time; or some other climatically controlled groundwater mixing processes? What is the nature of the calcite cements in the concretions? These were critical question she addressed in her research. These are important questions because in her area kink folds with minor offsets are developed locally in the aeolianite and any supporting evidence for tectonic activity would be helpful.

Rob Tunnell, Franklin and Marshall, **Claudia Pezzia**, Trinity University, and **Terri Amborn**, Cal Poly Pomona, mapped Neogene and Quaternary marine terraces and Late Pleistocene aeolian deposits along the east side of Cape Liptrap. Those deposits had been poorly mapped previously and undated, but the terraces would be a critical dataset to constrain deformation along the southern Australian margin. Their field areas on Cape Liptrap lie west of and astride the Walkerville fault (Fig.1b). They discovered at least 8 marine terraces along the eastern side of Cape Liptrap that extend up to nearly 220m above mean sea level. As of this writing the cosmogenic analyses are about to be performed on the AMS at Australia National University, but we suspect terrace ages will range from the last interglacial (~125ka) to the early Miocene.

Kathy Bremar, The College of Wooster, devoted her efforts to an investigation of the depositional environments of the Haunted Hill gravels. The Haunted Hill gravels are, more or less, a basket term for all quartz-rich, mostly fluvial deposits that are pre-

Quaternary, probably Pliocene in age. Kathy determined through careful sedimentological analyses that these gravels span quite a range of depositional environments, from saprolite to braided streams, to marine terraces. Her discovery of some critical marine terraces may go a long way toward answering the question of offset along the Walkerville fault. Her investigation focused on the Yanakee region, east of the Walkerville fault (Fig. 1b). Correlation of those terraces across the Walkerville fault and onto Cape Liptrap is critical to the determination of offset across the fault. She has a cosmogenic age that is also coming from ANU.

Sarah Flanagan, Smith College, collected barnacles and numerous shells for radiocarbon dating from some well exposed Holocene marine highstand deposits along the entire extent of Cape Liptrap. The reported age for the barnacles collected 1-2 meters above modern mean sea level was 5,570 +- 40 yBP. Her focus was to better constrain the elevation and age of that late Holocene marine event. As it turned out, her low, ~2-meter marine terrace on the Yanakee produced an OSL age of ~125ka, a rather startling age, but quite interesting for the marine terrace work because it indicates possible subsidence of the Yanakee region on the east side of the Walkerville fault.

Daniel Kapostasy, University of Dayton, decided to work in the abandoned, placer tin mines north of Toora. The host sediments are unconsolidated fluvial deposits, also lumped into the Haunted Hill gravels. As it turned out, some of those quarry walls revealed an incredible set of fault structures that shed light on Tertiary tectonic activity. Provenance studies suggest a source in the Wilson Promontory granites (Fig 1b). Today, mostly ocean occurs between the tin mines and the Prom!!

SUMMARY OF RESULTS

Taken together, these nine projects provide great insight into the Neogene and Quaternary landscape evolution of the Cape Liptrap region. Certainly there was significant compressional, post-Oligocene tectonism. This may have continued into the Neogene and Quaternary. The marine terraces on the west side of the Walkerville fault appear to be elevated relative to those on the east side. There was significant aeolian activity during sea level rise in the late Quaternary (70-85ka), depositing calcareous aeolinites along Arch Rock and a significant pulse of aeolian sedimentation of both calcareous sand (Morgan's Beach) and siliceous sands (east side of Cape Liptrap) during the Last Glacial Maximum (LGM) around 20-25ka.

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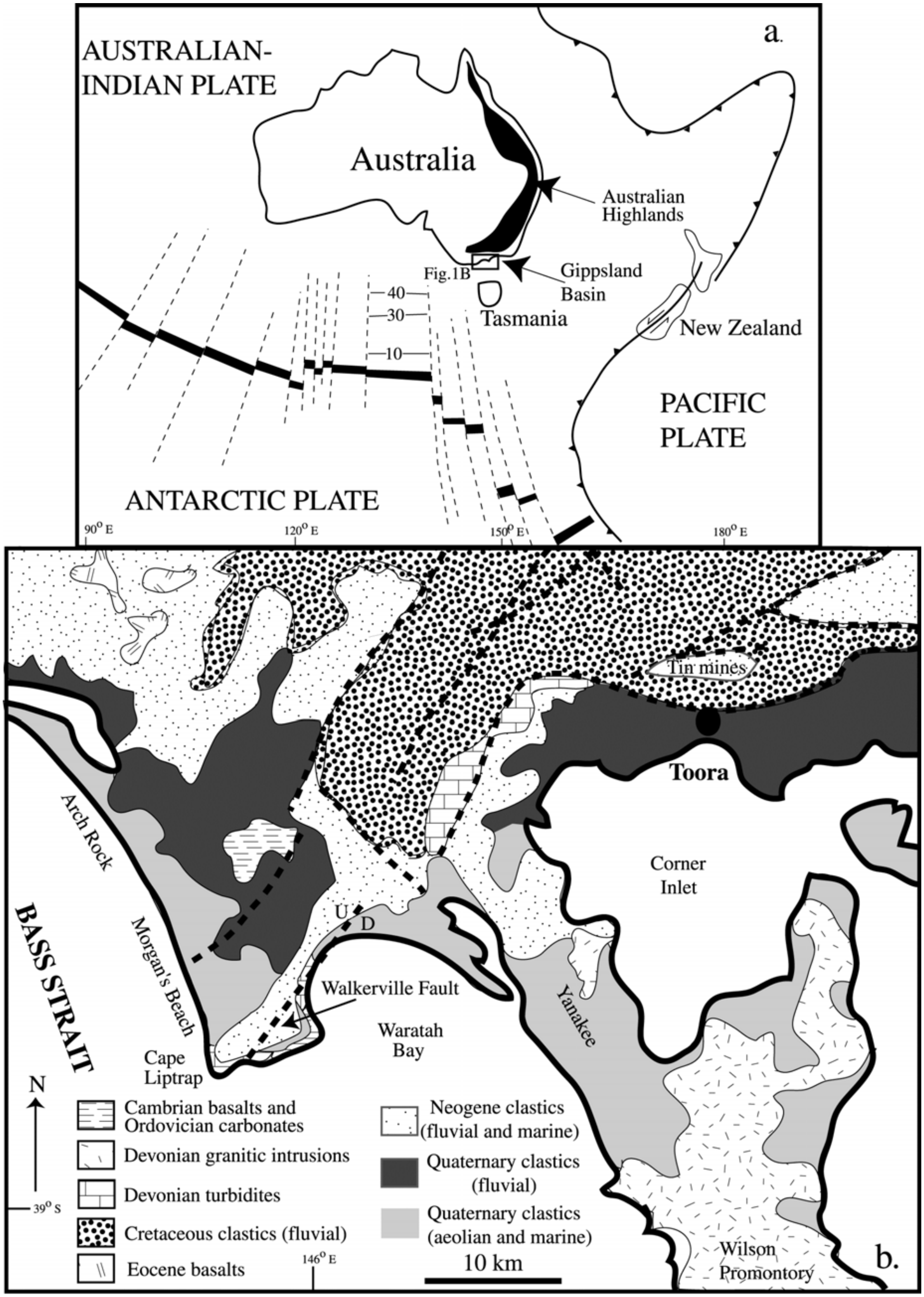

Figure 1. a) General tectonic setting of the Australian-Indian plate, the major physiographic expression of the Eastern and Southeastern Highlands, and location of the project (inset box), b) generalized geologic map of the project area showing major faults and distribution of geologic units for Cape Liptrap and Wilson Promontory. Toora, the project base camp, is shown for reference.