Scientific writing: Theses and papers

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Scientific writing

- Philosophy on theses and papers: what's expected of me and what do I want?
- Some 'Cardinal Rules' for writing
- Journal articles: Structure of an article (Title, Abstract, Introduction, Setting, Data methods and results, Discussion, Conclusion, Acknowledgements, References)
- The publication process
- Questions

My credentials

- More than 50 peer-reviewed articles published (17 first-author) and 16 ‘popular science’ articles
- 7 publications that were chapters straight out of my PhD thesis (EPSL, Bas Res, Tectonophys)
- 1 publication out of my MSc thesis (10 years later!)
- Frequently used reviewer for Geology (1), Tectonics (3), Tectonophysics (7), Geological Society America Bulletin (3), Geomorphology (1), Gondwana Research (1), Progress in Physical Geography (2), BSSA, NZJGG, etc
- Citations >800; h-index 17; i10-index 23

Supervisor’s philosophy on theses and papers – what’s expected of me?

- Undergrad research project –
- (1) original piece of work with ‘new’ data / ideas,
- (2) attendance at dept seminars,
- (3) discussion with other mentors in the department (students and staff),
- (4) establishment of ≥1 scientific relationships out of the department,
- (5) the best thesis you can write that is defensible in front of the department

Supervisor’s philosophy on theses and papers – what’s expected of me?

- MSc –
- (1) original piece of work,
- (2) some mentoring of undergraduate colleagues,
- (3) ≥1 first-author peer-reviewed publication **by time of thesis submission**,
- (4) ≥1 talk at a national or international conference,
- (5) ≥1 talk in department,
- (6) establishment of ≥1 scientific relationships out of the department,
- (7) the best thesis you can write that is defensible in front of New Zealand’s best scientists

Supervisor’s philosophy on theses and papers – what’s expected of me?

- PhD –
- (1) original piece of work including many of your own ideas,
- (2) mentoring of undergraduate and postgraduate colleagues,
- (3) a ‘world expert’ on your research topic,
- (4) several talks at international conferences and other universities,
- (5) a local to international reputation,
- (6) ≥3 peer-reviewed publications **by time of thesis submission,**
- (7) ≥2 talks in department,
- (8) establishment of ≥3 scientific relationships out of the department,
- (9) the best thesis you can write that is defensible in front of the world’s best scientists

What do I want by the end of my undergraduate degree?

- ***To be competitive for grad school at a top university:***
- (1) good grades, (2) good recommendations, (3) computational skill, (4) other interests, (5) something to distinguish you from other candidates (involvement in postgrad / staff research projects, special skill, a research publication, an article in a pop sci magazine)

- ***To be competitive for a geology position at a mining company, etc.***
- (1) technical experience in computer applications, (2) demonstrated ability to write (a paper?) and communicate (a dept talk or conference?), (3) good letters of reference – good reputation, (4) good grades!

What do I want by the end of my postgraduate degree?

- ***To be competitive for an academic job at a renowned university:***
- (1) 6-10 papers in high quality internationally regarded journals, (2) an international presence, (3) a reputation as ‘one of the best’ in your field, (4) significant teaching and mentoring experience, (5) ability to get research money
- ***To be competitive for a post-doc or position at a CRI like GNS:***
- (1) ≥3 papers in high quality internationally regarded journals, (2) a national presence, (3) reputation as an emerging and promising researcher, (4) ability to get research money
- ***To be competitive for a geology position at a mining company, etc.***
- (1) technical experience in computer applications, (2) ≥1 papers in high quality journals – ability to write, (3) ability to mentor colleagues, (4) talks at conferences, (5) good letters of reference – good reputation

What do I want by the end of my postgraduate degree?

- ***To be competitive for a PhD scholarship***
- (1) Top marks in all of your postgraduate classes (2) ≥1 papers in high quality journals, (3) a departmental reputation as a promising researcher

Do I want to be a 'problem chaser' (like Mark) or an expert in a particular field?

- *Both have merits and it depends on what drives you. In my opinion you can defend your thesis, publish great papers, and get a job regardless of which style you choose*

Mark’s ‘rules’ for writing

- When you are writing well (‘in the zone’), stay writing at all costs
- When you are not writing well, leave it, draft figures, clear your head, etc. Don’t get frustrated
- There are a variety of different writing styles and no real ‘rules’ – some people are very organized, others write haphazardly, some have all figures drafted beforehand and ‘write around them’, others do figures after, there is no right way
- Observations before interpretations!
- Find every reference before writing, and have the articles at hand, make sure your references are **up-to-date**
- Decide where the article is going to be submitted before writing, as there will be length and style restrictions and it affects how you write
- Decide authorship early on, this can change but it is good to have this sorted early (no problem with lots of authors)
- Decide your ‘target audience’ and write for them, not for you
- Draft figures at correction size and resolution for publication
- Write thesis chapters as scientific articles – do not write the thesis then pull it apart afterwards

Structure of an article

- Title, Authors and Affiliation, Abstract, Introduction, Geological Setting, Data methods and results, Discussion, Conclusion, Acknowledgements, References, Appendix

Title

- Catchy and broad, but not misleading
- Think about your audience – how would they find your article (Google?)
- Is putting a geographic reference into your article advantageous or limiting, and necessary?
- Snappy titles can be memorable or annoying
- I write the title of my paper before anything else, then agonize over it, then finalize it after the paper is written

The Holocene
1–12
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Holocene climate change in arid Australia from speleothem and alluvial records

Mark C. Quigley,[1] Travis Horton,[1] John C. Hellstrom,[2] Matthew L. Cupper[2] and Mike Sandiford[2]

Tectonic geomorphology of Australia

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Basin Research (2007) doi: 10.1111/j.1365-2117.2007.00336.x

Distinguishing tectonic from climatic controls on range-front sedimentation

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Geomorphic and cosmogenic nuclide constraints on escarpment evolution in an intraplate setting, Darling Escarpment, Western Australia

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Fatal attraction: living with earthquakes, the growth of villages into megacities, and earthquake vulnerability in the modern world

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Rock to Sediment—Slope to Sea with ^{10}Be—Rates of Landscape Change

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Authorship

- If you write the article, you are first author
- Less is not necessarily more – importance of collegiality, demonstrated ability to collaborate, more paper ‘pathways’, more opportunity for ‘two degrees of separation’
- Deciding who goes on the paper and who doesn’t

Holocene climate change in arid Australia from speleothem and alluvial records

The Holocene
1–12

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Mark C. Quigley,[1] Travis Horton,[1] John C. Hellstrom,[2] Matthew L. Cupper[2] and Mike Sandiford[2]

U–Pb SHRIMP zircon geochronology and *T–t–d* history of the Kampa Dome, southern Tibet

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Modes of active intraplate deformation, Flinders Ranges, Australia

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Geomorphic and cosmogenic nuclide constraints on escarpment evolution in an intraplate setting, Darling Escarpment, Western Australia

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Letter

U/Pb dating of a terminal Pliocene coral from the Indonesian Seaway

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ARTICLE INFO

ABSTRACT

Abstract

- Describes study objectives (i.e., what hypothesis you were testing or what research question you were attempting to answer), methods used, main results, the interpretation and implications of the results
- Written so as to clearly convey as much information as possible in as few words as possible, and written as a single paragraph
- Powerful, concise sentences that will entice browsers to look on
- Results before interpretation
- I always write my abstract first, to get focused on what the paper is about, then write the paper, then re-write the abstract

ABSTRACT

Structural, stratigraphic, and thermochronologic studies provide insight into the formation of basement-cored uplifts within the Colorado Plateau–Basin and Range transition zone in the Lake Mead region. Basement lithologic contacts, foliations, and ductile shear zones preserved in the core of the Virgin Mountain anticline parallel the trend of the anticline and are commonly reactivated by brittle fault zones, implying that basement anisotropy exerted a strong influence on the uplift geometry of the anticline. Potassium feldspar $^{40}Ar/^{39}Ar$ thermochronology indicates that basement rocks cooled from ≥250–325 °C to ≤150 °C in the Mesoproterozoic and remained at shallow crustal levels (<5–7 km) until they were exhumed to the surface. Apatite fission-track ages and track length measurements reveal a transition from slow cooling beginning at 30–26 Ma to rapid cooling at ca. 17 Ma, which we interpret to mark the change from regional post-Laramide denudational cooling to rapid extension-driven exhumational cooling by ca. 17 Ma. Middle Miocene conglomerates (ca. 16–11 Ma) flanking the anticline contain locally derived basement clasts with ca. 20 Ma apatite fission-track ages, implying rapid exhumation rates of ≥500 m m.y.$^{-1}$. The apparently complex geometry of the anticline resulted from the superposition of first-order processes, including isostatic footwall uplift and extension-perpendicular shortening, on a previously tectonized and strongly anisotropic crust. A low-relief basement-cored uplift may have formed during the Late Cretaceous–early Tertiary Laramide orogeny; however, the bulk of uplift, exhumation, and deformation of the Virgin Mountain anticline occurred during middle Miocene crustal extension.

Abstract

Structural and thermochronological studies of the Kampa Dome provide constraints on timing and mechanisms of gneiss dome formation in southern Tibet. The core of Kampa Dome contains the Kampa Granite, a Cambrian orthogneiss that was deformed under high temperature (sub-solidus) conditions during Himalayan orogenesis. The Kampa Granite is intruded by syn-tectonic leucogranite dikes and sills of probable Oligocene to Miocene age. Overlying Paleozoic to Mesozoic metasedimentary rocks decrease in peak metamorphic grade from kyanite + staurolite grade at the base of the sequence to unmetamorphosed at the top. The Kampa Shear Zone traverses the Kampa Granite — metasediment contact and contains evidence for high-temperature to low-temperature ductile deformation and brittle faulting. The shear zone is interpreted to represent an exhumed portion of the South Tibetan Detachment System. Biotite and muscovite $^{40}Ar/^{39}Ar$ thermochronology from the metasedimentary sequence yields disturbed spectra with 14.22 ± 0.18 to 15.54 ± 0.39 Ma cooling ages and concordant spectra with 14.64 ± 0.15 to 14.68 ± 0.07 Ma cooling ages. Petrographic investigations suggest disturbed samples are associated with excess argon, intracrystalline deformation, mineral and fluid inclusions and/or chloritization that led to variations in argon systematics. We conclude that the entire metasedimentary sequence cooled rapidly through mica closure temperatures at ~14.6 Ma. The Kampa Granite yields the youngest biotite $^{40}Ar/^{39}Ar$ ages of ~13.7 Ma immediately below the granite–metasediment contact. We suggest that this age variation reflects either varying mica closure temperatures, re-heating of the Kampa Granite biotites above closure temperatures between 14.6 Ma and 13.7 Ma, or juxtaposition of rocks with different thermal histories. Our data do not corroborate the "inverse" mica cooling gradient observed in adjacent North Himalayan gneiss domes. Instead, we infer that mica cooling occurred in response to exhumation and conduction related to top-to-north normal faulting in the overlying sequence, top-to-south thrusting at depth, and coeval surface denudation.

Keywords: Tibet; Himalaya; Gneiss domes; $^{40}Ar/^{39}Ar$ thermochronology

Abstract

New high-resolution MC-ICPMS U/Th ages and C and O isotopic analyses from a Holocene speleothem in arid south-central Australia provide evidence for increased effective precipitation (EP) relative to present at *c.* 11.5 ka and *c.* 8–5 ka, peak moisture at 7–6 ka, and onset of an arid climate similar to present by *c.* 5 ka. $\delta^{18}O$ and $\delta^{13}C$ time-series data exhibit marked (>+1‰) contemporaneous excursions over base-line values of −5.3‰ and −11.0‰, respectively, suggesting pronounced moisture variability during the early middle Holocene 'climatic optimum'. Optically stimulated luminescence and ^{14}C ages from nearby terraced aggradational alluvial deposits indicate a paucity of large floods in the Late Pleistocene and at least five large flood events in the last *c.* 6 ka, interpreted to mark an increased frequency of extreme rainfall events in the middle Holocene despite overall reduced EP. Increased EP in south-central Australia during the early to middle Holocene resulted from (1) decreased El Niño-Southern Oscillation (ENSO) variability, which reduced the frequency of El Niño-triggered droughts, (2) the prevalence of a more La Niña-like mean climatic state in the tropical Pacific Ocean, which increased available atmospheric moisture, and (3) a southward shift in the Intertropical Convergence Zone (ICTZ), which allowed tropical summer storms associated with the Australian summer monsoon (ASM) to penetrate deeper into the southern part of the continent. The onset of heightened aridity and apparent increase in large flood frequency at *c.* 5 ka is interpreted to indicate the establishment of an ENSO-like climate in arid Australia in the late Holocene, consistent with a variety of other terrestrial and marine proxies. The broad synchroneity of Holocene climate change across much of the Australian continent with changes in ENSO behavior suggests strong teleconnections amongst ENSO and the other climate systems such as the ASM, Indian Ocean Dipole, and Southern Annular Mode.

Keywords

alluvial deposits, Australian summer monsoon, ENSO, Holocene climate change, Indian Ocean dipole, precipitation, Southern Annular Mode, speleothem

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Letter

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ABSTRACT

Pristine detrital *Platygyra* corals were discovered in an exhumed package of syn-orogenic marine sediments on the island of Timor in the eastern Indonesian region and dated using U–Pb techniques. A single coral from the upper part of the sequence yields a $^{238}U/^{206}Pb$–$^{207}Pb/^{206}Pb$ concordia age of 2.66 ± 0.14 (2σ) Ma that is supported by coral $^{87}Sr/^{86}Sr$ chemostratigraphy and foraminiferal biostratigraphy from bounding strata. Minor U-series disequilibrium is best explained by U mobility within the last ~150 ka, as pore water chemistry was altered during exhumation, and is unlikely to have affected $^{238}U/^{206}Pb$ and the apparent sample age by more than 1–2%. The ability to date corals beyond the limits of ^{14}C and U/Th techniques provides the opportunity to improve the temporal resolution of associated marine chronostratigraphic records. In this instance, we refine the timing of Timor's emergence from beneath the waters of the Indonesian Seaway (*IS*) and the initiation of turbiditic deposition at the study site to between ca. 3.35 and 2.66 Ma. These results have implications for the evolution of topography and *IS* oceanic pathways in the active orogenic belts along the northern fringes of the Australian Plate.

Introduction

- The powerful first sentence (I agonize over it)
- Moving from the general to the specific
- First paragraph: stating the big questions and broad relevance, what is a critical void or misunderstanding in our current knowledge
- Second paragraph: Some detail about what is known about the problem, why it is controversial, setting up for your story
- Third paragraph: What is unique about your study, why is was undertaken, why it is important, what was learned (optional to actually give the answer here, or just cast the question)
- Probably the most important part of your paper next to the abstract

Introduction

Global ecosystems and human populations have been affected by changes in the frequency, magnitude and seasonal distribution of rain over the Holocene (Mayewski *et al*., 2004). Precipitation proxy data from the Holocene can provide insight into past connections between weather, climate and environments of relevance to understanding contemporary interactions. Additionally, paleoprecipitation data provide pre-industrial baselines upon which to assess whether changing rainfall distributions and magnitudes reflect anthropogenically influenced climate change (McInnes *et al*., 2003; Zhang *et al*., 2007). Speleothems (secondary $CaCO_3$ cave deposits) provide high-resolution proxy records of 'effective' moisture that can be related to long-term rainfall variability (e.g. Asmerom *et al*., 2007; Drysdale *et al*., 2006, 2007). Coarse alluvial terrace deposits provide evidence for large paleofloods and can be dated to determine paleoflood frequency (e.g. Keefer *et al*., 2003; Wells, 1990). By combining these approaches, past spatial and temporal relationships between effective moisture (e.g. mean annual precipitation, precipitation-evaporation indices) and moisture variability (e.g. large floods) can be resolved, with relevance for understanding the evolution of major climatic phenomenon such as ENSO (e.g. Gomez *et al*., 2004).

A variety of studies have identified the middle Holocene

First paragraph

INTRODUCTION

Large earthquakes occur intermittently in stable intraplate settings and may significantly impact developed and natural landscapes. The Australian continent experiences a magnitude ≥6.0 earthquake about every five years, as indicated by the historical database (McCue 1990). While the historical record of these events provides an insight into the contemporary Australian intraplate stress field (Clark & Leonard 2003), such datasets span relatively short time intervals (<200 y) and are therefore unlikely to encompass an earthquake of maximum magnitude for most areas (Sandiford *et al.* 2004). Seismic-hazard assessments of intracontinental regions based on historical seismicity may thus underestimate seismic risk (Clark & McCue 2003) and inadequately characterise long-term fault behaviour.

First paragraph

First paragraph

Introduction

The evolution of mountainous topography results from the dynamic interplay between tectonic forces, climate and erosion. For relief to develop in mountainous catchments, rates of fluvial incision into the landscape must exceed erosion rates on adjacent summit surfaces. Intervening hillslopes provide the bridge between these features, and may take on forms reflecting the relative rates of valley floor and summit surface erosion, as well as their internal lithologic and structural characteristics. In order to examine how mountainous landscapes respond to the tectonic and climatic forces imposed upon them, it is therefore critical to establish quantitative measures of bedrock erosion rate at summit surfaces, hillslopes and valley floors.

First paragraph

1. Introduction

The tectonic opening and closing of oceanic pathways influence global thermohaline circulation (Berggren and Hollister, 1977), marine productivity (Schneider and Schmittner, 2006), and climate (Mudelsee and Raymo, 2005). Exhumed marine sequences in or adjacent to oceanic pathway systems (e.g., Central American seaway, Indonesian Seaway) provide opportunities to decipher tectonic, topographic, physical and chemical oceanographic pathway changes with relevance for marine faunal evolution (e.g. Jackson et al., 1996), salinity and temperature changes in adjacent oceans (e.g. Karas et al., 2009), major climate systems (e.g. von der Heydt and Dijkstra, 2011), and human evolution (Cane and Molnar, 2001). The ability to study these processes is partially

Second paragraph

INTRODUCTION

Tectonism and climate are the primary external processes governing continental erosion, sedimentation and landscape evolution. Tectonic uplift creates elevated terrain and provides increased potential energy to the agents of erosion, such as fluvial systems. Seismic shaking associated with tectonic events may generate rubble and, in mountainous regions, trigger landslides, thereby increasing sedimentary inputs into catchment systems (Keefer, 1994; Allen & Hovius, 1998; Dadson *et al.*, 2004; Quigley *et al.*, 2007a). Climate controls the spatial and temporal distribution of erosional agents (streams and glaciers) and the vegetative cover that protects the landscape from erosion. Climatically induced changes in source catchment palaeogeography and/or hydrologic regimes may exert a strong influence on sediment generation and transport (e.g. Pederson *et al.*, 2000). In addition, the frequency and magnitude of large floods capable of significantly modifying continental landscapes may be strongly influenced by climate (Molnar, 2001; Molnar *et al.*, 2006). The ability to distinguish tectonic from climatic forcing on landscape evolution hinges on the development of robust geologic and chronometric datasets that may be evaluated in the context of well-dated tectonic events and palaeo-climatic regimes.

Alluvial fans are ubiquitous features of mountainous range fronts worldwide and provide a spatial and temporal record of source catchment erosion and basin sedimentation over geologic time scales (e.g. Bull, 1964; Denny, 1965; Ritter *et al.*, 1995; Whipple & Traylor, 1996; Calvache *et al.*, 1997). A primary focus of recent research has been to consider how tectonic and climatic processes influence alluvial fan morphological properties and sedimentary styles, and how fans respond to changes in these external parameters (e.g. Harvey *et al.*, 2005). Tectonic activity is now commonly recognized as the primary controlling factor in dictating alluvial fan properties such as location, setting and morphology, primarily through tectonic influences on drainage basin relief and fan accommodation space (Denny, 1965; Bull, 1977; Whipple & Traylor, 1996; Allen & Hovius, 1998; Allen & Densmore, 2000; Densmore *et al.*, 2007). Climate appears to have a dominant control in determining alluvial fan sequence stratigraphy, including the distribution of debris-flow, sheetflood and channelized fluvial deposits and fan aggradation–dissection intervals (Bull, 1991; Harvey & Wells, 1994; Harvey, 2004). Early studies on alluvial fans from the southwest USA emphasized the role of catchment lithology on alluvial fan morphology (Bull, 1964, 1991; Hooke & Rohrer, 1977) and sequence stratigraphy (Blair, 1999). However, these interpretations were questioned on the basis of spatial

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Second paragraph

Australia is generally considered a tectonically stable continental region (Johnston *et al.* 1994), where ancient land surfaces predominate (Twidale & Bourne 1975; Ollier 1978; Twidale 1983). While this is manifestly true for much of the continent, in some areas the coincidence of enhanced contemporary seismicity and surprisingly youthful geomorphology imply an important role for neotectonic landsculpting. One such region is the Flinders Ranges of South Australia, one of the most seismically active and geomorphically rugged parts of the continent (Sprigg 1945; Sandiford 2003). A number of workers have described Quaternary thrusting along range-bounding faults (Williams 1973; Ollier 1978; Bourman & Lindsay 1989, Célèrier *et al.* 2005), with fault slip rates in the range of 20–150 m per million years (Sandiford 2003). Sandiford (2003) traced this neotectonic regime back to at least 5 Ma based on regional unconformities between Upper Miocene and Pliocene sequences, and suggested that as much as half of the present elevation of the Flinders–Mt Lofty Ranges may be attributed to the presently active regime.

INTRODUCTION

The documentation of earthquake-induced surface ruptures (e.g., Clark, 1972) is a fundamental component of fault scaling relationships used for seismic-hazard analysis, engineering design criteria, and studies of fault rupture dynamics (e.g., Wells and Coppersmith, 1994; Wesnousky, 2008). Fault rupture data also enable estimation of static stress changes during earthquakes that provide insight into fault strength (e.g., Griffith et al., 2009) and the modeling of past and future earthquakes (e.g., Price and Bürgmann, 2002). Considerable variability exists in the surface rupture length (*SRL*) of moderately sized (i.e., M_w 7.0 ± 0.1) historical continental earthquakes, from nil (e.g., the 2010 M_w 7.0 Haiti earthquake; Prentice et al., 2010) to many tens of kilometers (e.g., 60 km *SRL* for the 1940 M_w 7.0 Imperial Valley, California, quake; Trifunac and Brune, 1970), highlighting the importance of combining geologic with seismologic and geodetic data sets in rupture analysis. Short or absent surface ruptures for continental earthquakes may reflect a concentration of coseismic slip at depth (Wesnousky, 2008) and/or complex ruptures on several faults without surface breaks (e.g., Hayes et al., 2010).

The 2010 M_w 7.1 Darfield (Canterbury) earthquake, henceforth referred to as the "Darfield" earthquake, occurred at 04:35 on 4 September 2010 New Zealand local time (16:35, 3 Sep-

Transitioning First to Second paragraph

Third paragraph

In this paper, we present new U–Pb SHRIMP spot ages from orthogneiss and leucogranite intrusions exposed in the core of the Kampa Dome. We combine these results with new structural and metamorphic data and previously published $^{40}Ar/^{39}Ar$ thermochronology (Quigley et al., 2006) to reconstruct temperature–time and deformational histories for rocks within the Kampa Dome. Our results indicate that (1) the Kampa granite is a Cambrian pluton that was strongly deformed and metamorphosed at high temperatures (~400–700 °C) during Himalayan orogenesis, (2) the contact between the Kampa granite and overlying metasedimentary rocks is a high-strain zone that preserves evidence for episodes of top-to-N and top-to-S ductile shearing and later brittle deformation, and (3) structural, metamorphic and geochronologic datasets are consistent with, but not necessarily unique to, the surfacing of

This study presents a new palaeoseismic analysis of the Late Quaternary tectonic activity associated with the Wilkatana and Burra Faults of the central Flinders Ranges and the Mundi Mundi Fault of the Barrier Ranges (Figure 1). Optically stimulated luminescence ages from fault-related sediments are used to generate quantitative palaeoseismic estimates. This allows better understanding of the long-term behaviour of intracontinental faults, including their temporal and spatial distribution and their potential for large-magnitude earthquake recurrence. The role and significance of active faulting in shaping the youthful topography and geomorphology of the Flinders Ranges are also considered. Specifically, the magnitude of vertical bedrock uplift resulting from movement along range-bounding faults was estimated in order to quantify the geomorphic signature associated with the active tectonic regime. Our results highlight the potential of intracontinental faults to impact the landscape, despite generally low slip rates and long recurrence intervals.

generation in mountainous regions.

This paper provides a quantitative analysis of the rates and processes of bedrock erosion for a mountainous catchment floored by resistant, variably foliated and ubiquitously jointed granitic bedrock. We describe and compare the erosional processes operating at summit surfaces, hillslopes and valley floors and use ^{10}Be concentrations in bedrock and alluvial sediment to provide a measure of the rates at which these processes operated in recent (late Quaternary) geologic time. Our results are placed into tectonic and climatic contexts in order to explain how an anomalously rugged, high relief mountain belt has developed in the middle of a continent generally known for its tectonic quiescence and climatic aridity.

agricultural framework. This provided >100 displaced markers (Fig. 2) that could be measured to determine *SRL* and coseismic displacements.

In this paper, we use real-time kinematic (RTK) and differential (D) GPS surveying, tape measurements, and airborne light detecting and ranging (LiDAR) to document the Greendale fault (GF) surface rupture during the 2010 Darfield earthquake. The rapid collection of field surface rupture data provides an opportunity to reduce the uncertainties in the displacement measurements and geometrical characteristics of earthquake surface rupture. We compare these data with data from other historical surface ruptures associated with earthquakes of similar M_w, and discuss the broader implications for fault behavior, M_w-displacement-*SRL* scaling relationships, and seismic-hazard analysis.

Third paragraph

Geolgical Setting

- Broad to specific
- If required, compartmentalize (e.g., climate section, tectonics section)
- Be clever about what you need to say that is **relevant** for what’s coming, but don’t overdo it
- Reference ALL / ORIGINAL early work if there is space, but be concise

GEOLOGIC SETTING

Flinders Ranges

The Flinders Ranges form part of a north–south trending, rugged upland system extending more than 600 km inland from the southern coast of South Australia to the Lake

Wilkatana area

The Wilkatana area is located within the central Flinders Ranges approximately 40 km north of Port Augusta, South Australia (Fig. 1). The catchments encompass an area

Topography, geology, climate, geomorphology, features of most relevance (e.g., alluvial fans)

Study sites: locations, descriptions and justification

The Flinders Ranges form part of a rugged upland system extending from the southern Australian coast south of Adelaide to the Lake Eyre Basin in the north (Figure 1). The ranges are flanked by lowland piedmonts comprising colluvial, alluvial and aeolian deposits with intercalated paleosols and large, internally draining playa lake basins (Lakes Frome, Eyre and Torrens). Mean annual precipitation across the region is low (<310 mm/yr) and only weakly seasonal. The speleothem site has a summer (December–February) to winter (June–August) rainfall ratio of 2.1:1 while the alluvial fan site has a summer–winter rainfall ratio of 1:1.4 (Figure 1). Summer rainfall is commonly associated with southward incursions of tropical northerly systems (Schwerdtfeger and Curran, 1996), while winter rainfall is dominantly supplied by extra-tropical cyclones and cold fronts originating in the Indian and Southern Oceans (Evans *et al*., 2009; Meneghini *et al*., 2007). Precipitation is strongly influenced by topography, with surrounding piedmonts and basins receiving less than 200 mm/yr and the high ridges receiving over 400 mm/yr. Rainfall is greatly exceeded by annual evaporation, accounting for the lack of permanent water bodies save a few small, spring-fed streams. However, during sporadic, intense summer rainfall events (e.g. 14 March 1989 event, 273 mm in 24 h in the Lake Torrens area; www.bom.gov) large streams

The Yudnamutana speleothem was obtained from a ~10 m deep overhang cave (30°11′16″S, 139°24′58″E) elevated ~ 8 m above the adjacent Yudnamutana Creek in the northern Flinders Ranges (Figure 1). Yudnamutana creek forms part of an antecedent, highly ephemeral drainage basin deeply incised (~600 m) into granite, gneiss and schist basement rocks that have been uplifted by thrust faulting along the tectonically active range front (Quigley *et al.*, 2007c). The cave is situated within highly fractured, U-rich Proterozoic granite (Coats, 1973). Recharge throughout the ranges is limited to direct infiltration of rainfall through bedrock fracture networks, with the bulk of water discharge associated with small, fault-related springs (Brugger *et al.*, 2005). The water-table in the ranges follows topography and lies up to ~9 m below the surface (Brugger *et al*., 2005), thus stream flow throughout the ranges is restricted to rare, infrequent flood events.

Within the Yudnamutana cave (Figure 2A), there is a cleft in the granite wall from which water has clearly flowed in the past. The cleft feeding this system has created a flowstone deposit with an area of ~0.25 m^2 on the wall beneath this outlet, of between about 10 and 40 mm in thickness (Figure 2B,C). We sampled the flowstone at its thickest point, with water probably channeled to, and flowing down, a ridge in the cave wall. Sample extraction revealed continuity of depositional units over its width and down onto the cave floor where they are interspersed with cave sediments. The position of the cave slightly above the creek floor beneath steep relief suggests that it provides a good proxy for

GEOLOGIC SETTING

New Zealand occupies the boundary zone between the Pacific and Australian plates, which converge obliquely at rates of 39–50 mm yr^{-1} (DeMets et al., 2010) (Fig. 1A). In the central South Island, continent-continent collision is characterized by dextral transpression across a series of predominantly NNE- to east-striking active faults throughout the Southern Alps, the Canterbury Plains, and offshore (Pettinga et al., 2001) (Figs. 1A and 1B). Geodetic data indicate ~2 mm yr^{-1} of contraction oriented at 277° ± 8° across the 125-km-wide Canterbury Plains block with a western boundary defined by the Porter's Pass–Amberley fault zone (PPAFZ; Fig. 1B) (Wallace et al., 2007). The stress field in the area of the Darfield earthquake is best characterized by a subhorizontal maximum compressive stress (s_1) trending ~115° ± 5° (Fig. 2) (Sibson et al., 2011). Structures in the Canterbury Plains block (Fig. 1B), such as the fault underlying the Hororata anticline (Jongens et al., 1999) and the Springfield fault (Forsyth et al., 2008), deform the post–last glacial alluvial outwash surface, implying Late Pleistocene or Holocene deformation. No evidence for prior surface-rupturing earthquakes was observed in the vicinity of the GF.

Keeping it short and concise:

This is the entire "Geol Setting" section for my Geology paper

Data methods and results

- The importance of being honest, even if you screwed up!
- A well written method and results section is one that can be duplicated by someone with the equipment but without the expertise
- However, you can reference other papers for specifics of methods
- Sample description, sampling and analytical procedure, results (with specific interpretations, but don’t confuse with Discussion section)
- I often start the section with a reiteration of why this data is being acquired, without duplicating

U/Th dating of the Yudnamutana speleothem

Sample description

The Yudnamutana speleothem consists of hundreds of 10–100 μm thick laminae ranging from clear, microcrystalline calcite-rich layers to red-brown and black layers rich in Fe-oxide, mica and smectitic clay (Figure 2B,C). Based on petrographic observation of the speleothem in thin section, the laminae compositional variability

Sampling and analytical procedure

Samples were extracted from individual translucent laminations of the flowstone by scratching shallow grooves on a polished section using a stainless steel needle and binocular microscope. Microcrystalline calcite layers were preferentially selected for dating

Results

Ten U/Th ages were calculated using $[^{230}Th/^{232}Th]_i$ of 10 ± 5, imparting age uncertainties of up to $\pm$ 1.0 ka (Figure 2C; Table 1). The speleothem contains little detrital Th and yields a series of ages ranging from 11.6±0.3 ka from the innermost lamination adjacent to the cave wall to 5.2±1.0 ka from the outermost lamination, indicating speleothem growth in the latest Pleistocene and early to middle Holocene. Speleothem thickness measurements between successive ages were used to generate an age versus growth rate plot (Figure 2D). The earliest detected growth at the outermost *c*. 6 ka site and yields an age of 5.2±1.0 ka, suggesting a slowing of speleothem growth from *c*. 6 to 5 ka and termination of growth by *c*. 5 ka. Although speleothem growth from *c*. 8 to 5 ka was likely episodic on timescales finer than the resolution of U-Th age dating as indicated by the presence of hundreds of laminations, the absence of discernable unconformities during this time interval implies no major interruptions in mid-Holocene growth. The age–growth rate plot reveals speleothem growth at rates of 2–4 mm/kyr from *c*. 8 to 7 ka, a marked increase to rates of 10–20 mm/kyr at *c*. 7–6 ka, a decrease to rates of 0.2–0.4 mm/kyr at *c*. 6–5 ka and a cessation of growth at *c*. 5 ka. Providing speleothem ages provide a proxy for local climate conditions, our results suggest more a more effectively humid climate at *c*. 12–11 ka and *c*. 8–5 ka marked by a peak in humidity between 7 and 6 ka, followed by the onset of effectively arid conditions similar to present at 5–4 ka. It is highly likely that the moisture required to sustain the rapid *c*. 7–6 ka growth rates would have been enough to sustain perennial stream flow in Yudnamutana Creek. It is inconceivable that one river system in the range could be hydrologically active for at least 2000 years without at the very least reflecting a regional *in situ* precipitation signal. This is explored in more detail in the Discussion.

End of section – setting up for the Discussion

Discussion

- Sums up ideas, the juicy bit of the paper, the place for interpretations, speculations, etc
- Build from specific to broad (opposite of Intro)
- Often helps to compartmentalize
- First paragraph, quick summary of results from above, then expansion on these results
- Second paragraph, detailed explanation of specific interesting attributes of the data, exploration of novel concepts
- Third paragraph, stepping out to examine how results fit into broader context
- Forth paragraph, really going for it, place for arm waving, big interpretations, etc

6. Discussion

6.1. Summary and interpretation of $^{40}Ar/^{39}Ar$ results

Many of the mica analyses presented here yield ^{40}Ar/^{39}Ar spectra with varying degrees of discordance. As a result ^{40}Ar/^{39}Ar ages for these samples cannot be

6.2. Formation of the Kampa Dome

Thermochronologic and structural data may be combined to constrain the timing and mechanisms

Followed by expansion to other domes…

The Kampa Dome shares several common features with 'typical' extensional metamorphic core complexes (Brun and Van Den Driessche, 1994; Tirel et al., 2004); including (1) the presence of a domed, major detachment zone (Kampa Shear Zone) that places younger metasedimentary rocks on older granitic rocks, (2) the occurrence of high-temperature to low-temperature

Discussion

Summary of speleothem and alluvial records

Thin section observation and U-Th dating reveals that the Yudanamutana speleothem was deposited at *c*. 11 ka and

Origin of the middle-Holocene 'climatic optimum' in southern Australia

Contemporary annual rainfall variability in the study region is modulated by complex interactions amongst broad-scale atmospheric arrangements (SO, ASM, SAM) associated with sea surface temperature gradients in the Pacific, Indian, and Southern Oceans (Evans *et al*., 2009; Meneghini *et al*., 2007) and influenced by local topography. In general, lower (higher) than average

The onset of the 'modern' climatic regime: implications for contemporary climate change and climate-weather interactions

After *c*. 5 ka, changes in ENSO dynamics, including the more frequent occurrence of El Niños, are likely have impacted on the other climate modes that deliver rainfall to southern Australia. These impacts would have included a reduced strength of the ASM, decreasing the amount of summer rainfall delivered to the Yudna-

Conclusion

- Not always required for papers
- Like abstract, but can be more summative and specific, given that the authors have now read the paper
- What was learned
- Opportunities for future research

- http://www.ehow.com/how_4617129_write-scientific-conclusion-dissertation.html

CONCLUSIONS

The Wilkatana Fans provide a record of the spatial–temporal distribution of alluvial fan building and associated facies changes in the late Quaternary. The well-constrained tectonic and climatic history of the area provides a robust context in which to interpret these records. Tectonic uplift increased sedimentary inputs into the Wilkatana Fans via increasing catchment gradients and relief, increasing catchment sediment input and increasing footwall 'accommodation space' in response to tectonically induced footwall basin flexural subsidence. The mode of tectonism exerted an influence in the volume and geometry of alluvial fans throughout the region. However, both facies changes and sediment aggradation–dissection cycles were out-of-synch with dated tectonic events, implying that an aspect of climate was responsible for their compositional and temporal distributions. Rapidly oscillating and increasingly arid late Pleistocene climates produced a landscape that was highly susceptible to regolith-stripping episodes from $> ca.$ 71 to $< ca.$ 55 ka, as indicated by aggraded debris flow deposits. Progressive regolith erosion culminated with the transition to a bedrock landscape by *ca.* 32 ka, as indicated by the deposition of conglomeritic units markedly distinct from earlier debris flow deposits. Lower total rainfall and rainfall variability at the LGM was reflected by low-energy fluvial sedimentation and aeolian deposition within the fans. Holocene cut-and-fill terraces mark the return of punctuated, high discharge flood events capable of transporting coarse material. The age of these sequences may be used as a proxy for large-magnitude flood recurrence in the mid-late Holocene and quite possibly to provide estimates of large flood recurrence in the future.

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support the argument that there has been no significant displacement along the Darling Scarp during the Quaternary. A word of caution is, however, required since at ~30 Myr ago, this region of Australia was at a latitude of ~45°S and the climate was likely substantially wetter than present (Martin, 2006). Hence, the assumption that the present day retreat rates of the knickpoints and scarp face are representative of the long term may be somewhat simplistic. Since erosion rates were likely to have been higher under a higher rainfall regime, the mid-Tertiary to early Neogene initiation obtained here are likely to be maximum values.

Conclusion

Low cosmogenic ^{10}Be erosion rates and erosion rate variability from bedrock outcrops comprising the Darling Scarp imply minimal relief production over the Quaternary, consistent with this feature being a slowly eroding, tectonically inactive feature. Knickpoint retreat rates are compatible with long-term rates derived from geological constraints and, if representative of longer term rates, are consistent with the interpretation that knickpoints formed during early Tertiary tectonic uplift and have been slowly propagating through the landscape since

then. High cosmogenic ^{10}Be concentrations in active stream channels indicate slow erosion that is inconsistent with tectonically modulated incision along the adjacent range-front, as has been proposed for other Australian landscapes (e.g. Flinders Ranges), and is more consistent with a fluvial response to slow, long wavelength, low amplitude southwest side up tilting of the Australian continent. Continental tilting may explain the disequilibrium longitudinal profiles in streams incised into the Darling Scarp. Comparison of the ^{10}Be cosmogenic nuclide concentrations of the aseismic Darling Scarp with seismically active Flinders Ranges suggest that ^{10}Be nuclide analysis is a very useful tool in determining whether a structure, or region, has been tectonically active over the timescales of cosmogenic nuclide accumulation, thus providing a potential palaeo-seismic tool with a range of up to 10^5 to 10^6 years.

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Acknowledgements, References, Appendix

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- Thanks to people who reviewed the manuscript (not really any point in thanking anonymous)
- Thanks to research grants

- References – pay attention to journal format

- Appendix – as above, listen to editorial advice but push if you disagree, I rarely use one

The submission process

- Several revisions, clearance from co-authors
- On-line submission
- Editor asks reviewers
- Reviewers respond and review ms
- Editor examines reviews and makes decision
- Author responds
- Repeat process
- Paper accepted
- Proofs received
- Paper published

Helpful resources

- http://abacus.bates.edu/~ganderso/biology/resources/writing/HTWsections.html