Research Proposals: How to Maximize Success in a Competitive Funding Environment

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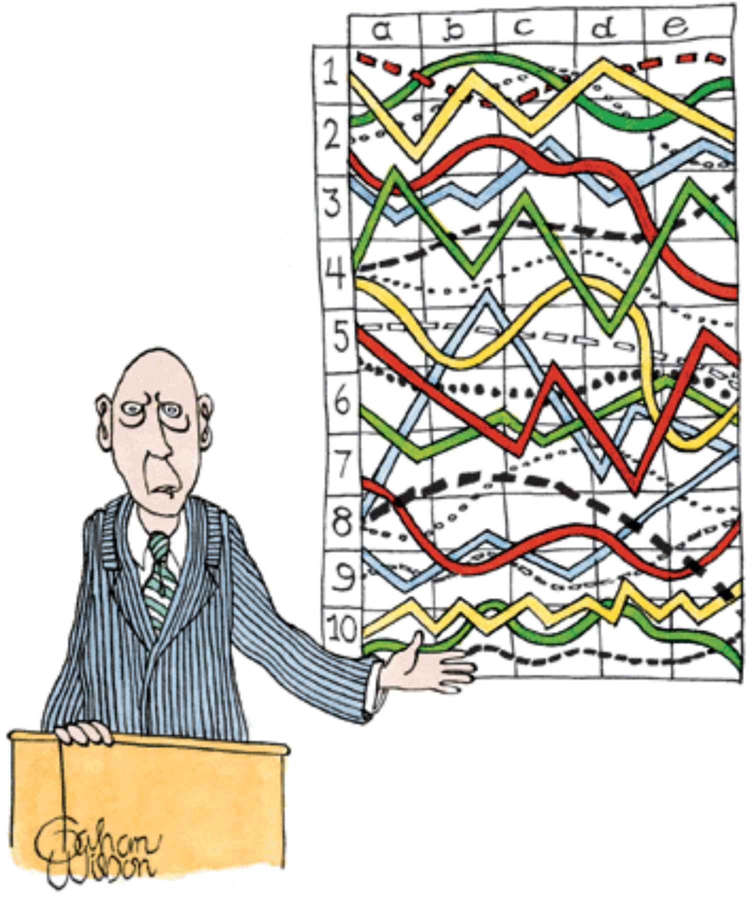


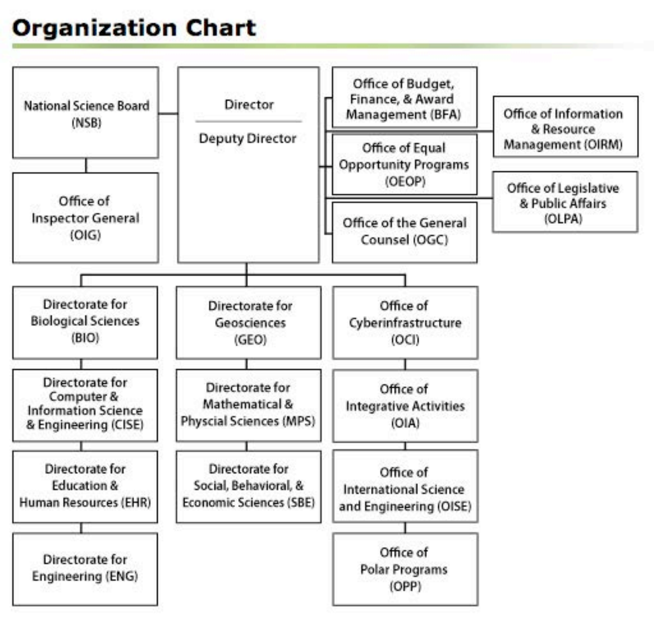
“I'll pause for a moment so you can let this information sink in.”

“I’ll pause for a moment so you can let this information sink in” New Yorker, Dec. 6, 2010

Writing proposals in Geosciences

- NSF- agency that provides grant support for basic science
- Epistemology- (Scientific reasoning- deduction vs. induction, empirical science and hypothesis testing)
- Development of a proposal "template"- the "hook"

National Science Foundation



Organization Chart

National Science Board (NSB)

Office of Inspector General (OIG)

Director

Deputy Director

Office of Budget, Finance, & Award Management (BFA)

Office of Equal Opportunity Programs (OEOP)

Office of the General Counsel (OGC)

Office of Information & Resource Management (OIRM)

Office of Legislative & Public Affairs (OLPA)

Directorate for Biological Sciences (BIO)

Directorate for Computer & Information Science & Engineering (CISE)

Directorate for Education & Human Resources (EHR)

Directorate for Engineering (ENG)

Directorate for Geosciences (GEO)

Directorate for Mathematical & Physcial Sciences (MPS)

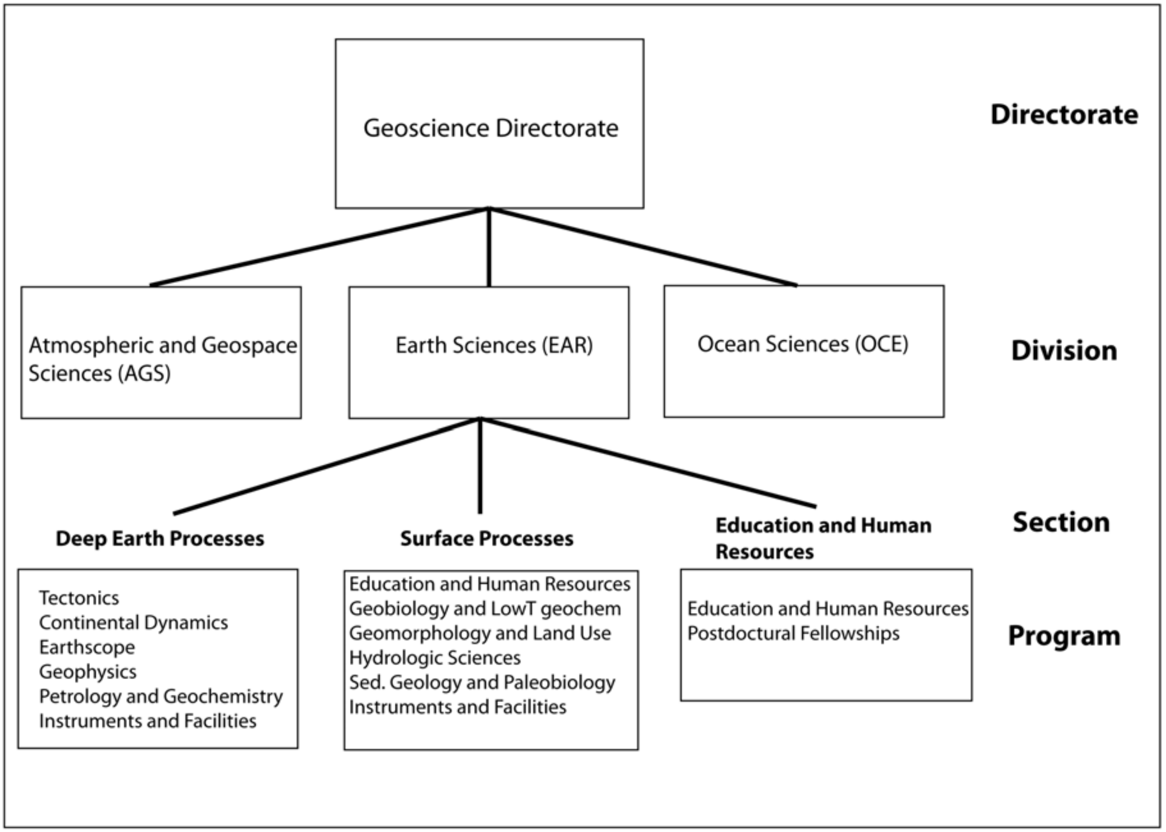
Directorate for Social, Behavioral, & Economic Sciences (SBE)

Office of Cyberinfrastructure (OCI)

Office of Integrative Activities (OIA)

Office of International Science and Engineering (OISE)

Office of Polar Programs (OPP)



Geoscience Directorate

Directorate

Atmospheric and Geospace Sciences (AGS)

Earth Sciences (EAR)

Ocean Sciences (OCE)

Division

Deep Earth Processes

Surface Processes

Education and Human Resources

Section

Tectonics
Continental Dynamics
Earthscope
Geophysics
Petrology and Geochemistry
Instruments and Facilities

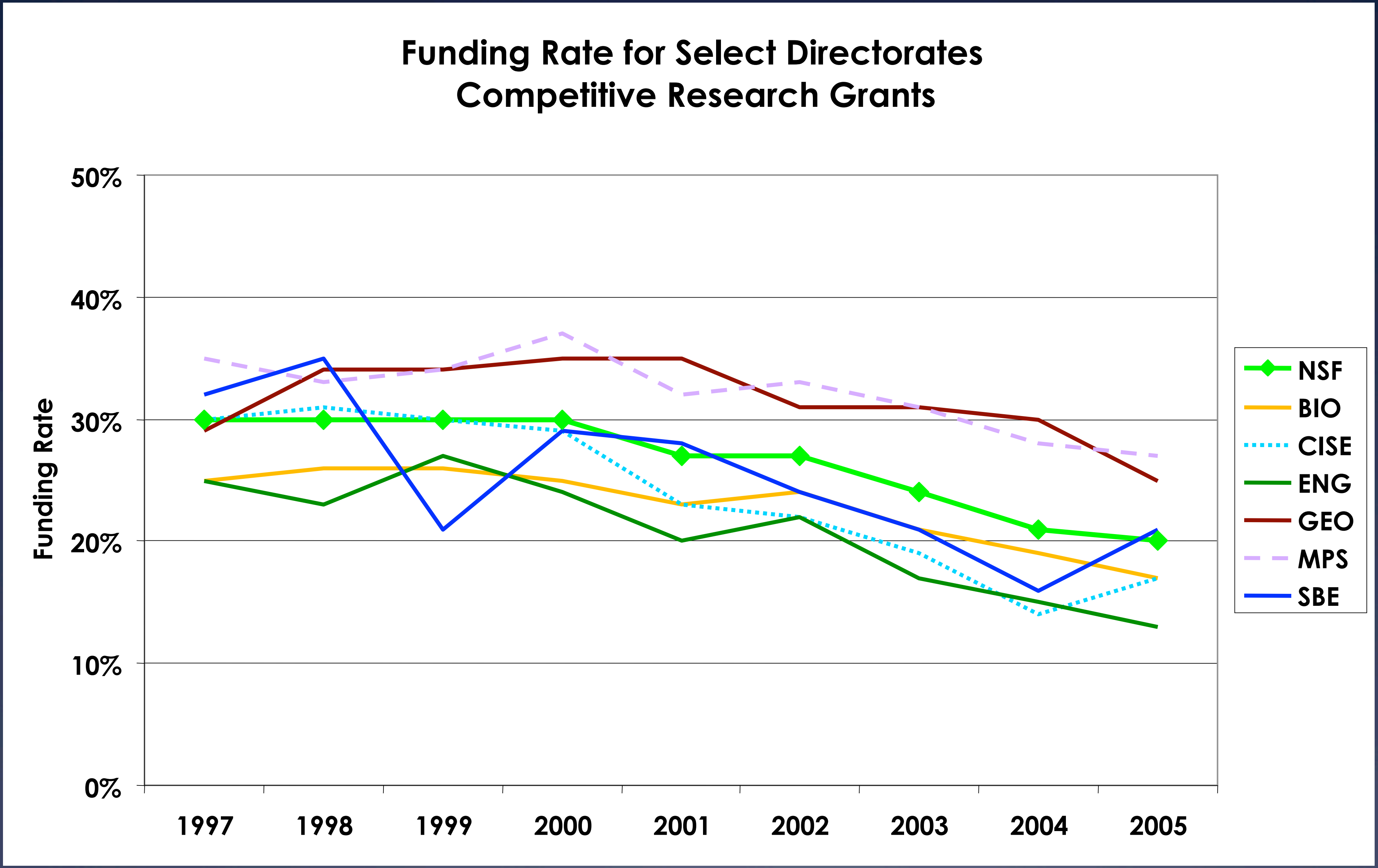
Education and Human Resources
Geobiology and LowT geochem
Geomorphology and Land Use
Hydrologic Sciences
Sed. Geology and Paleobiology
Instruments and Facilities

Education and Human Resources
Postdoctural Fellowships

Program

A competitive environment

All R&RA directorates experienced a decline in funding rates between FY 2000 and FY2005



Epistemology-How do we know what we know?

- Rationalism
  - Descartes (1596-1650)
  - Espinoza (1632-1677)
  - Leibniz (1646-1716)

- Empiricism
  - Locke (1632-1704)
  - Berkeley (1685-1753)
  - Hume (1711-1776)

Epistemology-How do we know what we know?

- Deductive
  - Temperature increases with depth.

  Exhumation decreases the depth

  Therefore………

  Exhumation causes cooling

Combine accepted facts in ways that forces one to accept the conclusion

- Inductive

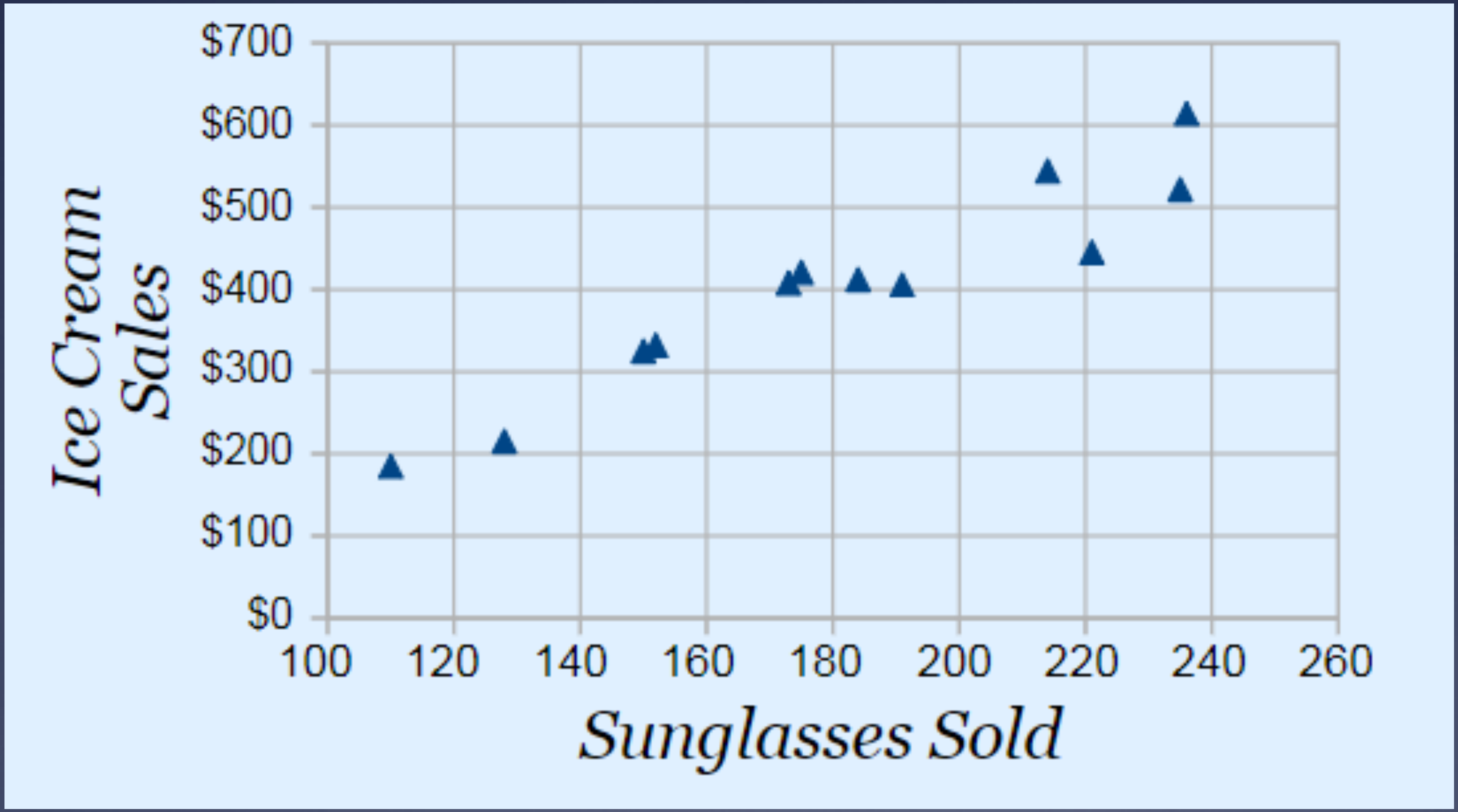
Use singular statements to infer universal statements

Inductive Reasoning

- Specific instances are translated into more general principles
- Example: I trip this light switch and the lights go off. Therefore I induce that EVERY time I trip the switch the lights will go off.
- Evaluating arguments by generalization can include questions like:
  - Are there enough examples?
  - Do the examples come from different times, places, and situations?
  - Are the examples specific enough?
  - Are there counterexamples?

Argument by Cause

- Attempts to establish a cause and effect relationship between two events
- Example:



Argument by Cause

- Ask yourself these questions:
  - Is there a “lurking 3rd variable”?
  - What is the certainty or strength of the relationship?
  - Is the cause necessary and/or sufficient?

Argument by analogy

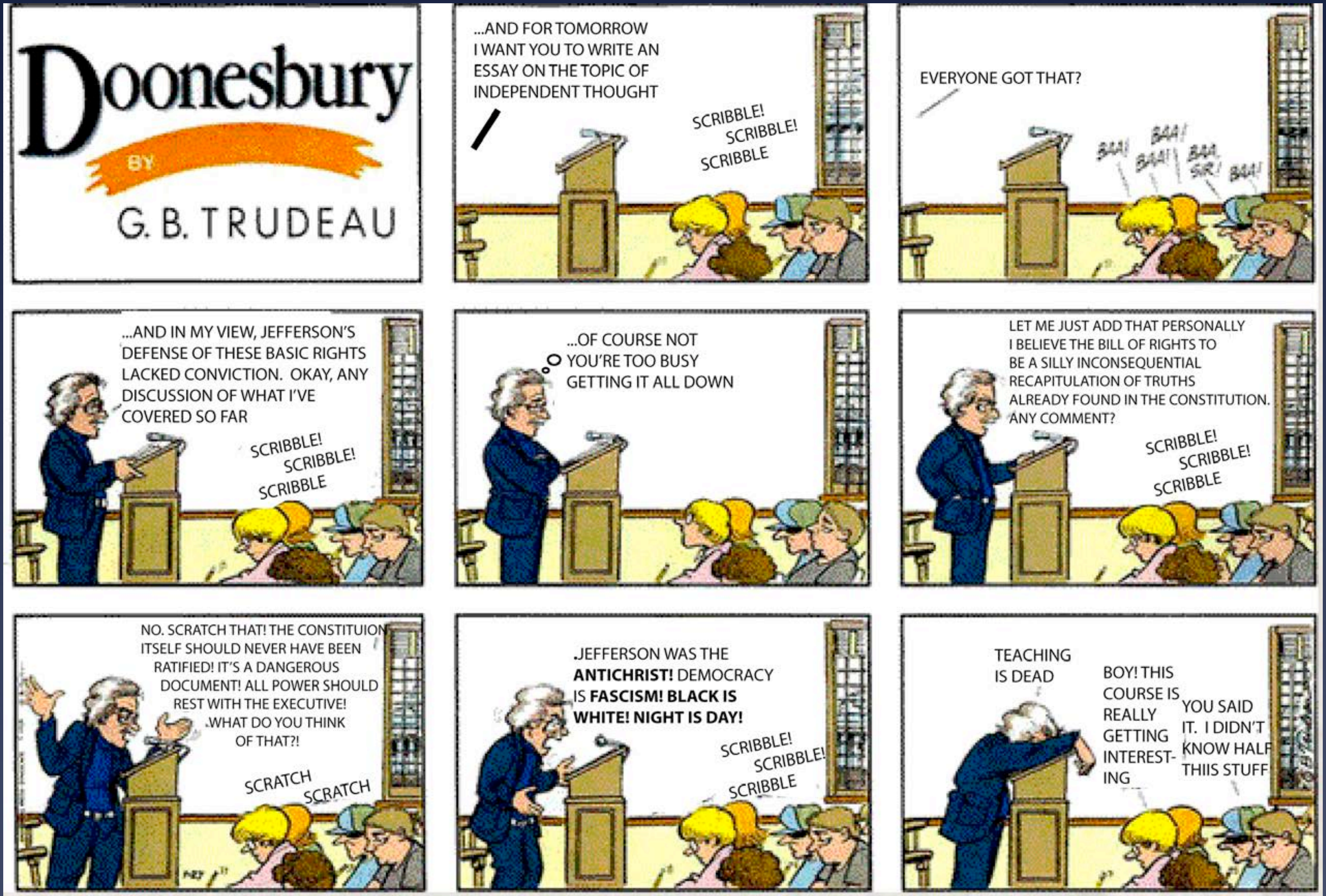
- What is true in one case is true in the other (arguments that use simile, metaphor, or comparison)
- Example: "The present is the key to the past"
- Ask yourself….
  - Are there significant points of similarity or difference?
  - Are the points of similarity crucial to the comparison?
  - Are the differences irrelevant to the comparison?

Argument by Authority

Something is true because a credible source says it is true

- Example: “The founding fathers worked tirelessly to end slavery” ---Michele Bachmann, Jan., 2011
- Ask yourself……
  - Is the authority qualified to make a judgment?
  - Is the authority trustworthy and honest?
  - Is the authority experienced?

Ex Cathedra learning



Garry B. Trudeau January 27, 1985

Proposals and “the scientific method”

- Singular statements vs. universal statements
- The problem with induction, or deriving universal statements from singular statements
- Popper’s (1902-1994) solution to the problem of induction
- Falsifiability-the demarcation between science and non-science
- Popper-Analogy between scientific knowledge and natural selection-all theories are temporary
- Criticisms of Popper- paradigms and verifiability-Is this really the way science “works”
- Implications for the Proposal review process

Popper (1934): A logic of scientific discovery

- "It should be noticed that a positive decision can only temporarily support the theory, for subsequent negative decisions may always overthrow it."
- "…anyone who envisages a system of absolutely certain, irrevocably true statements as the end and purpose of science will certainly reject the proposals I shall make here."
- "But how is the system that represents our world of experience to be distinguished? The answer is: by the fact that it has been submitted to tests and has stood up to tests. This means that it is to be distinguished by applying to it that deductive method…"

Popper (1934): A logic of scientific discovery

- "Now in my view, there is no such thing as induction. Thus, inference to theories from singular statements that are 'verified by experience' is inadmissable. Theories are, therefore, *never* empirically verifiable."
- "But I shall admit a system as empirical or scientific only if it is capable of being tested by experience. These considerations suggest that it is not the verifiability but the falsifiability of a system to be taken as a criterion of demarcation."
- "Its (i.e. the empirical method) aim is not to save the lives of untenable systems, but, on the contrary, to select the one which is by comparison the fittest by exposing them all to the fiercest struggle for survival."

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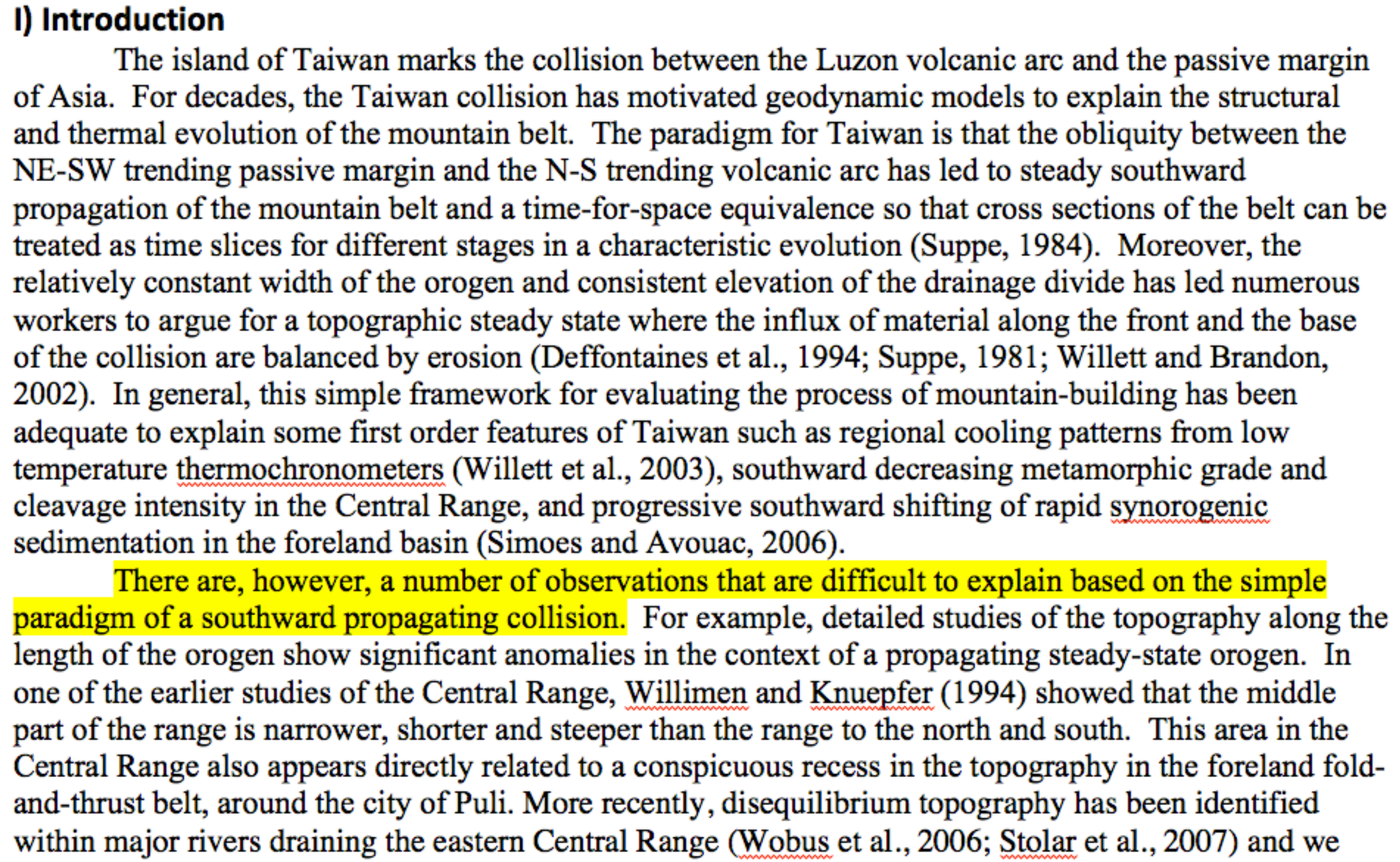
The Hook (ex.)

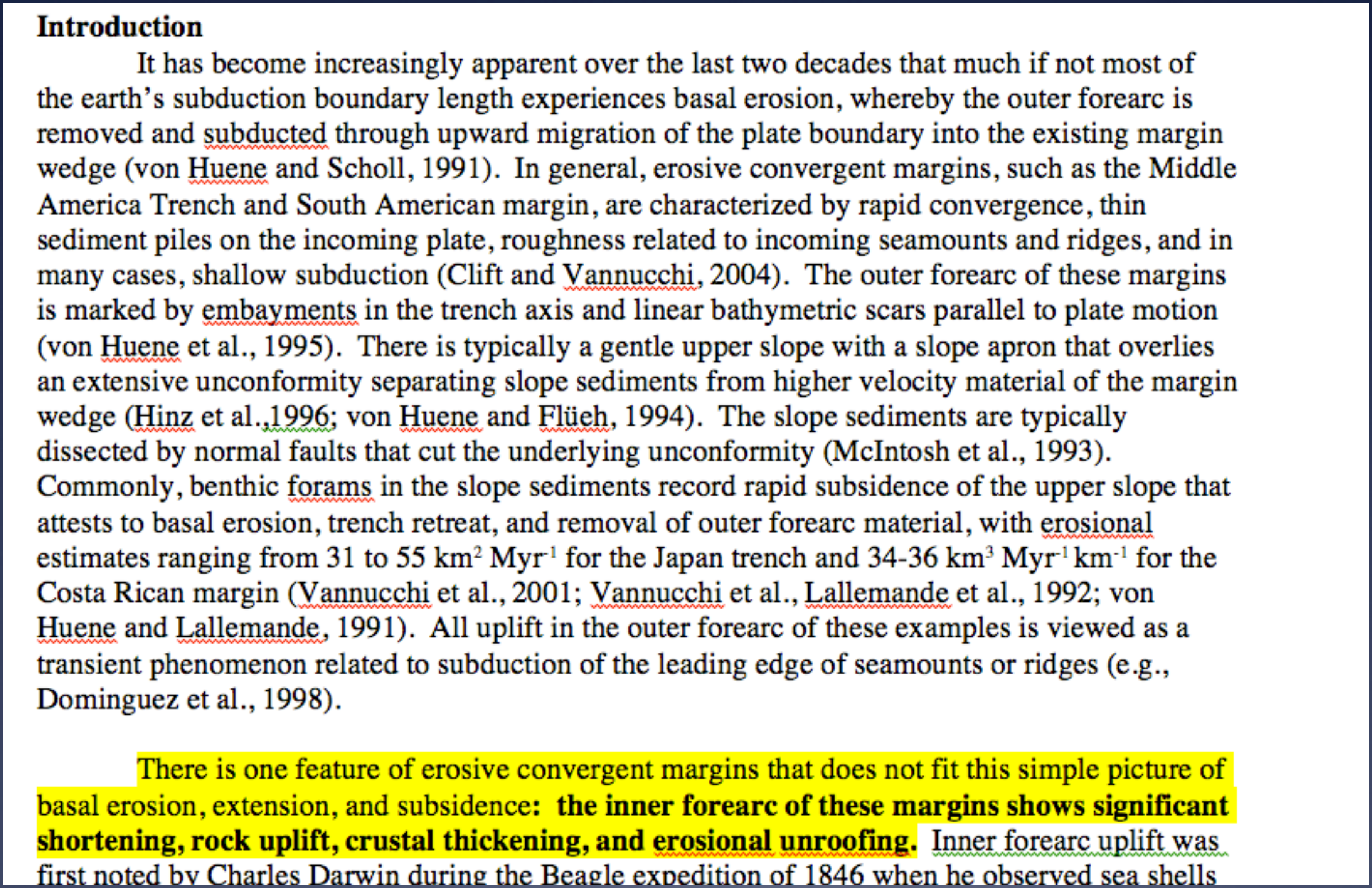


I) Introduction

The island of Taiwan marks the collision between the Luzon volcanic arc and the passive margin of Asia. For decades, the Taiwan collision has motivated geodynamic models to explain the structural and thermal evolution of the mountain belt. The paradigm for Taiwan is that the obliquity between the NE-SW trending passive margin and the N-S trending volcanic arc has led to steady southward propagation of the mountain belt and a time-for-space equivalence so that cross sections of the belt can be treated as time slices for different stages in a characteristic evolution (Suppe, 1984). Moreover, the relatively constant width of the orogen and consistent elevation of the drainage divide has led numerous workers to argue for a topographic steady state where the influx of material along the front and the base of the collision are balanced by erosion (Deffontaines et al., 1994; Suppe, 1981; Willett and Brandon, 2002). In general, this simple framework for evaluating the process of mountain-building has been adequate to explain some first order features of Taiwan such as regional cooling patterns from low temperature thermochronometers (Willett et al., 2003), southward decreasing metamorphic grade and cleavage intensity in the Central Range, and progressive southward shifting of rapid synorogenic sedimentation in the foreland basin (Simoes and Avouac, 2006).

There are, however, a number of observations that are difficult to explain based on the simple paradigm of a southward propagating collision. For example, detailed studies of the topography along the length of the orogen show significant anomalies in the context of a propagating steady-state orogen. In one of the earlier studies of the Central Range, Willimen and Knuepfer (1994) showed that the middle part of the range is narrower, shorter and steeper than the range to the north and south. This area in the Central Range also appears directly related to a conspicuous recess in the topography in the foreland fold-and-thrust belt, around the city of Puli. More recently, disequilibrium topography has been identified within major rivers draining the eastern Central Range (Wobus et al., 2006; Stolar et al., 2007) and we

The Hook (ex.)

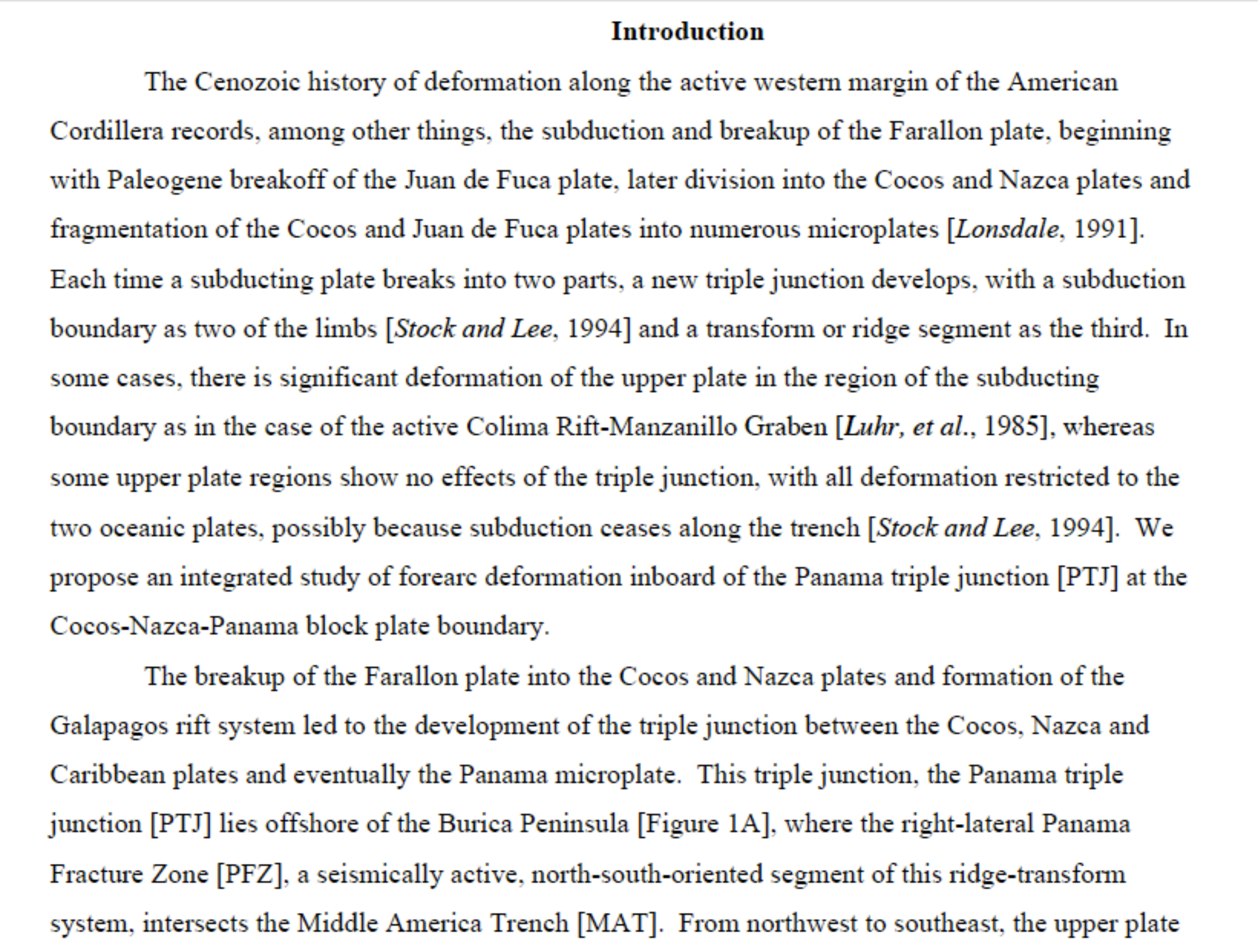


Introduction

It has become increasingly apparent over the last two decades that much if not most of the earth's subduction boundary length experiences basal erosion, whereby the outer forearc is removed and subducted through upward migration of the plate boundary into the existing margin wedge (von Huene and Scholl, 1991). In general, erosive convergent margins, such as the Middle America Trench and South American margin, are characterized by rapid convergence, thin sediment piles on the incoming plate, roughness related to incoming seamounts and ridges, and in many cases, shallow subduction (Clift and Vannucchi, 2004). The outer forearc of these margins is marked by embayments in the trench axis and linear bathymetric scars parallel to plate motion (von Huene et al., 1995). There is typically a gentle upper slope with a slope apron that overlies an extensive unconformity separating slope sediments from higher velocity material of the margin wedge (Hinz et al.,1996; von Huene and Flüeh, 1994). The slope sediments are typically dissected by normal faults that cut the underlying unconformity (McIntosh et al., 1993). Commonly, benthic forams in the slope sediments record rapid subsidence of the upper slope that attests to basal erosion, trench retreat, and removal of outer forearc material, with erosional estimates ranging from 31 to 55 km^2 Myr^{-1} for the Japan trench and 34-36 km^3 Myr^{-1} km^{-1} for the Costa Rican margin (Vannucchi et al., 2001; Vannucchi et al., Lallemande et al., 1992; von Huene and Lallemande, 1991). All uplift in the outer forearc of these examples is viewed as a transient phenomenon related to subduction of the leading edge of seamounts or ridges (e.g., Dominguez et al., 1998).

There is one feature of erosive convergent margins that does not fit this simple picture of basal erosion, extension, and subsidence: **the inner forearc of these margins shows significant shortening, rock uplift, crustal thickening, and erosional unroofing.** Inner forearc uplift was first noted by Charles Darwin during the Beagle expedition of 1846 when he observed sea shells

The Hook (ex.)

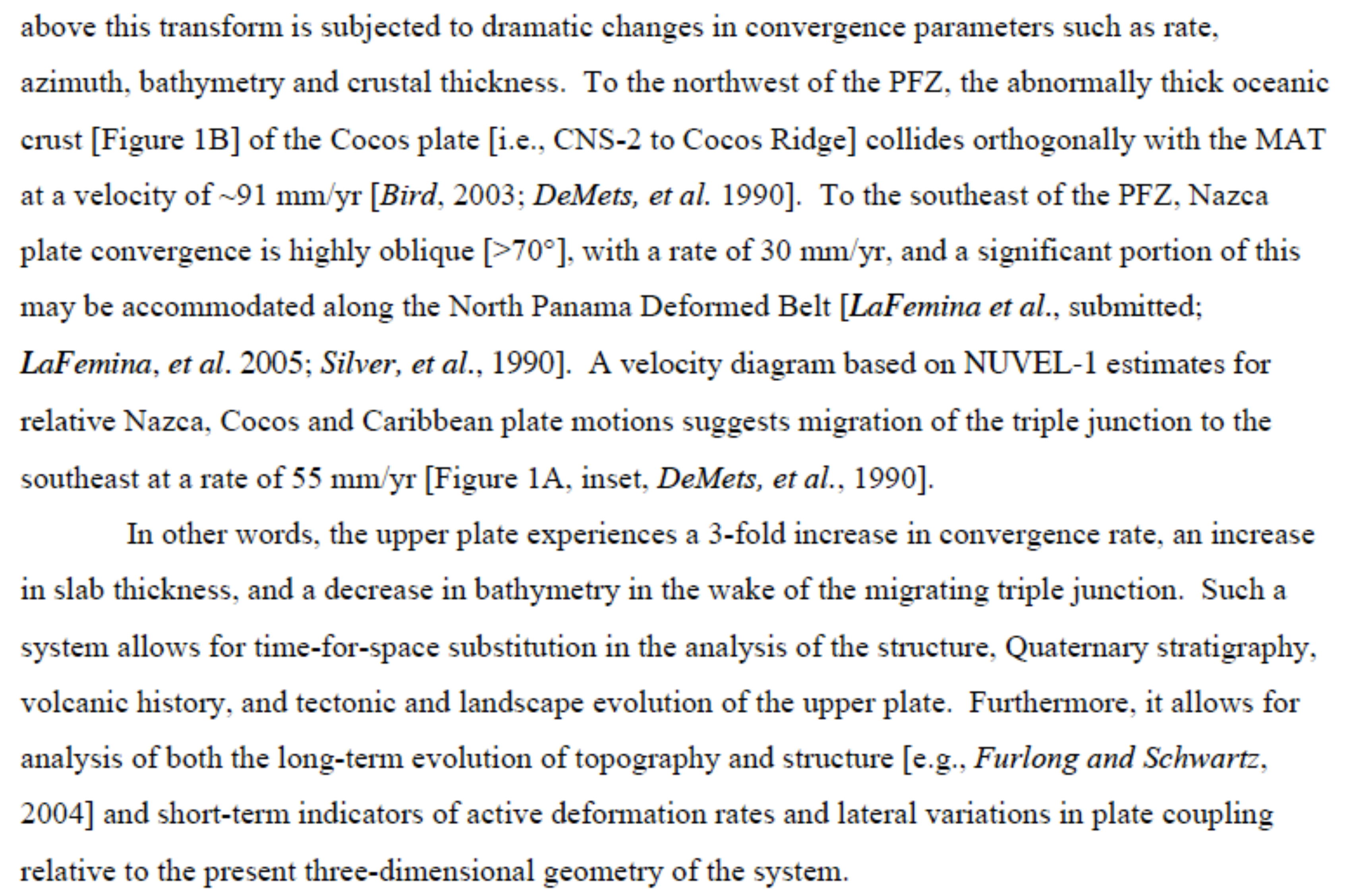


Introduction

The Cenozoic history of deformation along the active western margin of the American Cordillera records, among other things, the subduction and breakup of the Farallon plate, beginning with Paleogene breakoff of the Juan de Fuca plate, later division into the Cocos and Nazca plates and fragmentation of the Cocos and Juan de Fuca plates into numerous microplates [*Lonsdale*, 1991]. Each time a subducting plate breaks into two parts, a new triple junction develops, with a subduction boundary as two of the limbs [*Stock and Lee*, 1994] and a transform or ridge segment as the third. In some cases, there is significant deformation of the upper plate in the region of the subducting boundary as in the case of the active Colima Rift-Manzanillo Graben [*Luhr, et al.*, 1985], whereas some upper plate regions show no effects of the triple junction, with all deformation restricted to the two oceanic plates, possibly because subduction ceases along the trench [*Stock and Lee*, 1994]. We propose an integrated study of forearc deformation inboard of the Panama triple junction [PTJ] at the Cocos-Nazca-Panama block plate boundary.

The breakup of the Farallon plate into the Cocos and Nazca plates and formation of the Galapagos rift system led to the development of the triple junction between the Cocos, Nazca and Caribbean plates and eventually the Panama microplate. This triple junction, the Panama triple junction [PTJ] lies offshore of the Burica Peninsula [Figure 1A], where the right-lateral Panama Fracture Zone [PFZ], a seismically active, north-south-oriented segment of this ridge-transform system, intersects the Middle America Trench [MAT]. From northwest to southeast, the upper plate

The Hook (ex.)



above this transform is subjected to dramatic changes in convergence parameters such as rate, azimuth, bathymetry and crustal thickness. To the northwest of the PFZ, the abnormally thick oceanic crust [Figure 1B] of the Cocos plate [i.e., CNS-2 to Cocos Ridge] collides orthogonally with the MAT at a velocity of ~91 mm/yr [*Bird*, 2003; *DeMets, et al.* 1990]. To the southeast of the PFZ, Nazca plate convergence is highly oblique [>70°], with a rate of 30 mm/yr, and a significant portion of this may be accommodated along the North Panama Deformed Belt [*LaFemina et al.*, submitted; *LaFemina, et al*. 2005; *Silver, et al.*, 1990]. A velocity diagram based on NUVEL-1 estimates for relative Nazca, Cocos and Caribbean plate motions suggests migration of the triple junction to the southeast at a rate of 55 mm/yr [Figure 1A, inset, *DeMets, et al.*, 1990].

In other words, the upper plate experiences a 3-fold increase in convergence rate, an increase in slab thickness, and a decrease in bathymetry in the wake of the migrating triple junction. Such a system allows for time-for-space substitution in the analysis of the structure, Quaternary stratigraphy, volcanic history, and tectonic and landscape evolution of the upper plate. Furthermore, it allows for analysis of both the long-term evolution of topography and structure [e.g., *Furlong and Schwartz*, 2004] and short-term indicators of active deformation rates and lateral variations in plate coupling relative to the present three-dimensional geometry of the system.

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The hypothesis

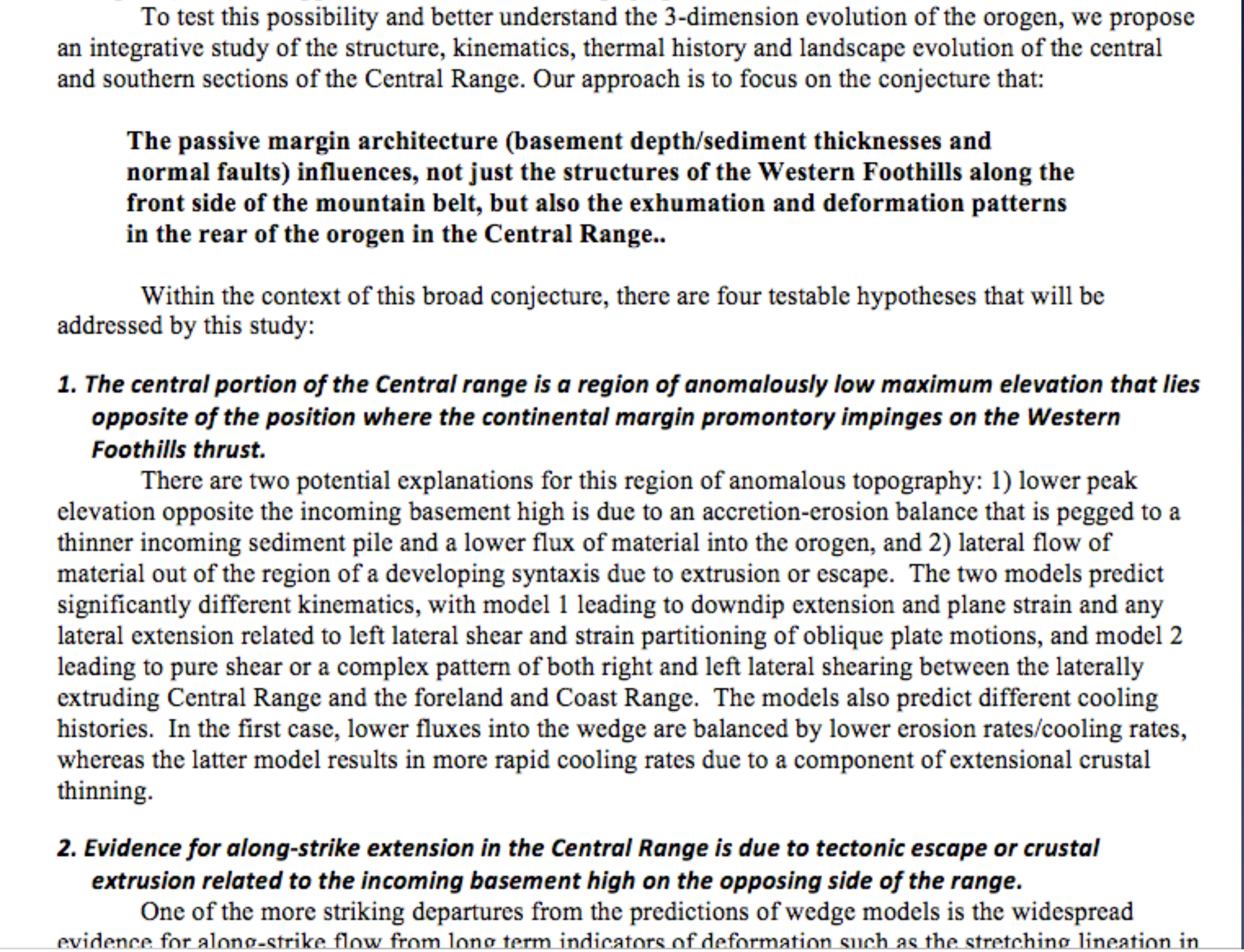
“I hypothesize that … will provide new insights into the processes of …”

“I hypothesize that …this new method for measuring X will be superior to previous methods”

“I hypothesize that, when I measure this value, it will be …”

Problems:	vague
	no way of falsifying
	singular vs. universal truths

The hypothesis (ex.)



To test this possibility and better understand the 3-dimension evolution of the orogen, we propose an integrative study of the structure, kinematics, thermal history and landscape evolution of the central and southern sections of the Central Range. Our approach is to focus on the conjecture that:

> **The passive margin architecture (basement depth/sediment thicknesses and normal faults) influences, not just the structures of the Western Foothills along the front side of the mountain belt, but also the exhumation and deformation patterns in the rear of the orogen in the Central Range..**

Within the context of this broad conjecture, there are four testable hypotheses that will be addressed by this study:

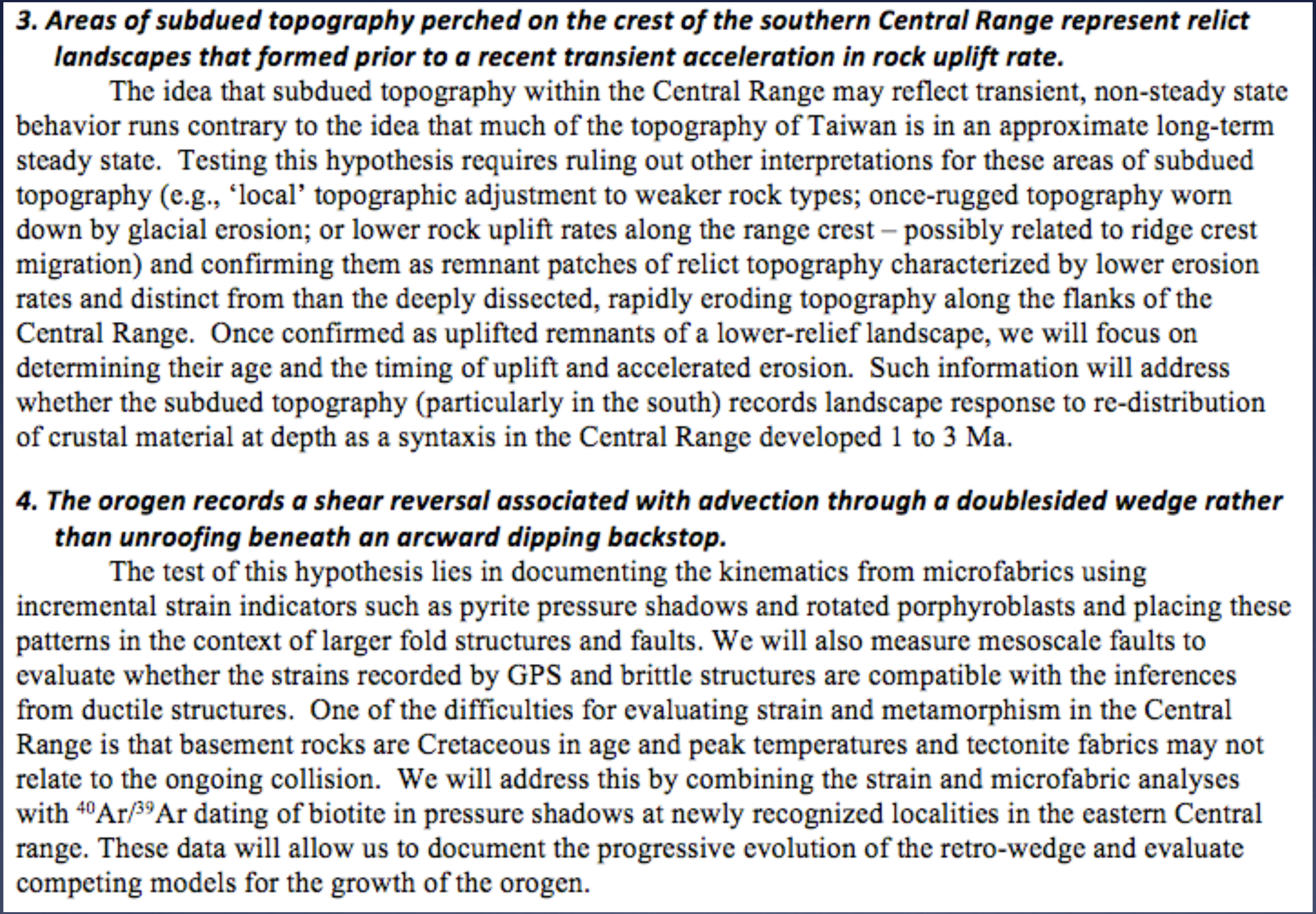
1. The central portion of the Central range is a region of anomalously low maximum elevation that lies opposite of the position where the continental margin promontory impinges on the Western Foothills thrust.

There are two potential explanations for this region of anomalous topography: 1) lower peak elevation opposite the incoming basement high is due to an accretion-erosion balance that is pegged to a thinner incoming sediment pile and a lower flux of material into the orogen, and 2) lateral flow of material out of the region of a developing syntaxis due to extrusion or escape. The two models predict significantly different kinematics, with model 1 leading to downdip extension and plane strain and any lateral extension related to left lateral shear and strain partitioning of oblique plate motions, and model 2 leading to pure shear or a complex pattern of both right and left lateral shearing between the laterally extruding Central Range and the foreland and Coast Range. The models also predict different cooling histories. In the first case, lower fluxes into the wedge are balanced by lower erosion rates/cooling rates, whereas the latter model results in more rapid cooling rates due to a component of extensional crustal thinning.

2. Evidence for along-strike extension in the Central Range is due to tectonic escape or crustal extrusion related to the incoming basement high on the opposing side of the range.

One of the more striking departures from the predictions of wedge models is the widespread evidence for along-strike flow from long term indicators of deformation such as the stretching lineation in

The hypothesis (ex.)



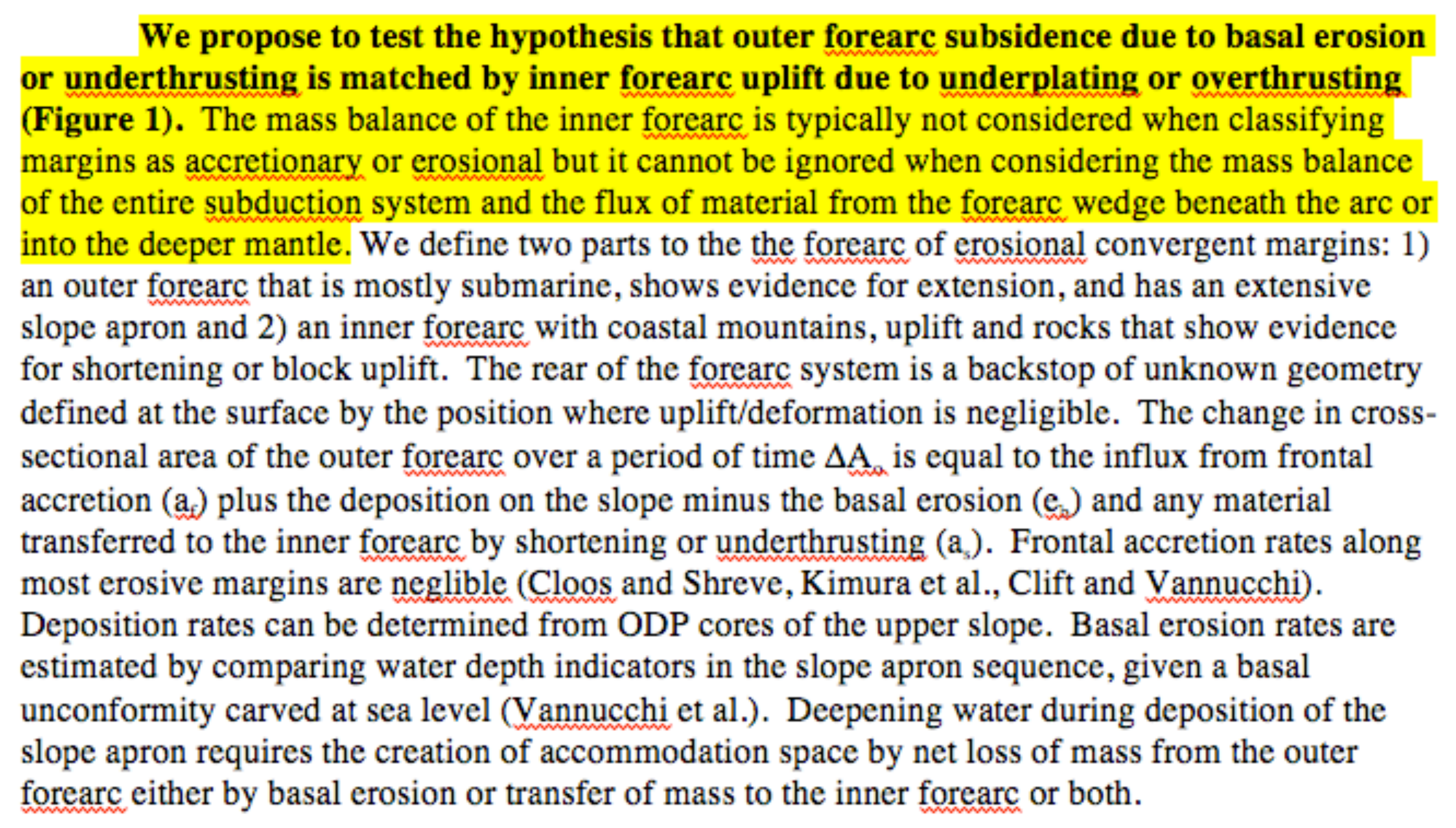
3. Areas of subdued topography perched on the crest of the southern Central Range represent relict landscapes that formed prior to a recent transient acceleration in rock uplift rate.

The idea that subdued topography within the Central Range may reflect transient, non-steady state behavior runs contrary to the idea that much of the topography of Taiwan is in an approximate long-term steady state. Testing this hypothesis requires ruling out other interpretations for these areas of subdued topography (e.g., 'local' topographic adjustment to weaker rock types; once-rugged topography worn down by glacial erosion; or lower rock uplift rates along the range crest – possibly related to ridge crest migration) and confirming them as remnant patches of relict topography characterized by lower erosion rates and distinct from than the deeply dissected, rapidly eroding topography along the flanks of the Central Range. Once confirmed as uplifted remnants of a lower-relief landscape, we will focus on determining their age and the timing of uplift and accelerated erosion. Such information will address whether the subdued topography (particularly in the south) records landscape response to re-distribution of crustal material at depth as a syntaxis in the Central Range developed 1 to 3 Ma.

4. The orogen records a shear reversal associated with advection through a doublesided wedge rather than unroofing beneath an arcward dipping backstop.

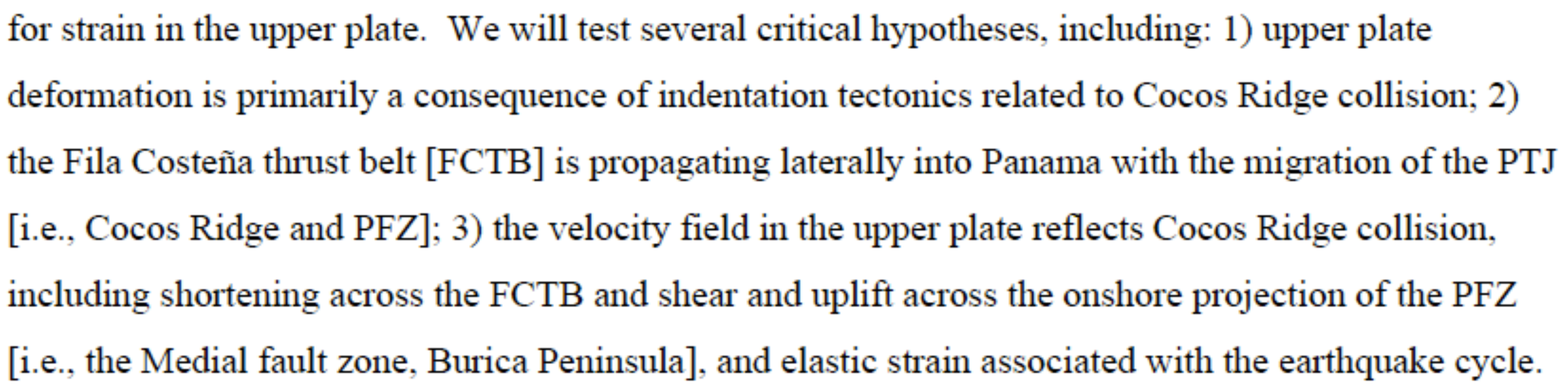
The test of this hypothesis lies in documenting the kinematics from microfabrics using incremental strain indicators such as pyrite pressure shadows and rotated porphyroblasts and placing these patterns in the context of larger fold structures and faults. We will also measure mesoscale faults to evaluate whether the strains recorded by GPS and brittle structures are compatible with the inferences from ductile structures. One of the difficulties for evaluating strain and metamorphism in the Central Range is that basement rocks are Cretaceous in age and peak temperatures and tectonite fabrics may not relate to the ongoing collision. We will address this by combining the strain and microfabric analyses with ^{40}Ar/^{39}Ar dating of biotite in pressure shadows at newly recognized localities in the eastern Central range. These data will allow us to document the progressive evolution of the retro-wedge and evaluate competing models for the growth of the orogen.

Hypothesis (ex.)



We propose to test the hypothesis that outer forearc subsidence due to basal erosion or underthrusting is matched by inner forearc uplift due to underplating or overthrusting (Figure 1). The mass balance of the inner forearc is typically not considered when classifying margins as accretionary or erosional but it cannot be ignored when considering the mass balance of the entire subduction system and the flux of material from the forearc wedge beneath the arc or into the deeper mantle. We define two parts to the the forearc of erosional convergent margins: 1) an outer forearc that is mostly submarine, shows evidence for extension, and has an extensive slope apron and 2) an inner forearc with coastal mountains, uplift and rocks that show evidence for shortening or block uplift. The rear of the forearc system is a backstop of unknown geometry defined at the surface by the position where uplift/deformation is negligible. The change in cross-sectional area of the outer forearc over a period of time ΔA_o is equal to the influx from frontal accretion (a_f) plus the deposition on the slope minus the basal erosion (e_b) and any material transferred to the inner forearc by shortening or underthrusting (a_s). Frontal accretion rates along most erosive margins are neglible (Cloos and Shreve, Kimura et al., Clift and Vannucchi). Deposition rates can be determined from ODP cores of the upper slope. Basal erosion rates are estimated by comparing water depth indicators in the slope apron sequence, given a basal unconformity carved at sea level (Vannucchi et al.). Deepening water during deposition of the slope apron requires the creation of accommodation space by net loss of mass from the outer forearc either by basal erosion or transfer of mass to the inner forearc or both.

Hypothesis (ex.)



for strain in the upper plate. We will test several critical hypotheses, including: 1) upper plate deformation is primarily a consequence of indentation tectonics related to Cocos Ridge collision; 2) the Fila Costeña thrust belt [FCTB] is propagating laterally into Panama with the migration of the PTJ [i.e., Cocos Ridge and PFZ]; 3) the velocity field in the upper plate reflects Cocos Ridge collision, including shortening across the FCTB and shear and uplift across the onshore projection of the PFZ [i.e., the Medial fault zone, Burica Peninsula], and elastic strain associated with the earthquake cycle.

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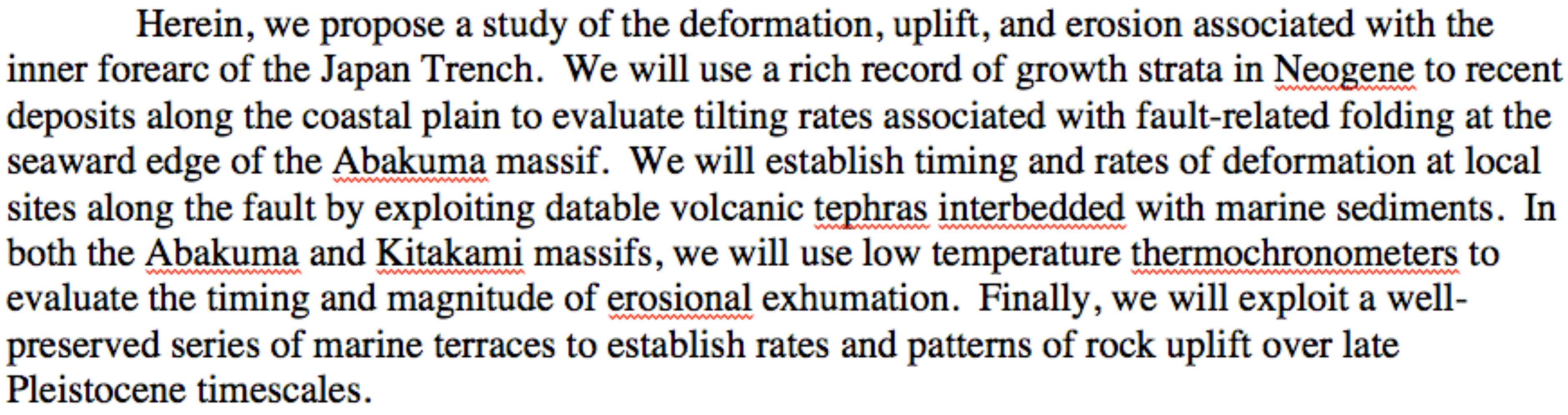
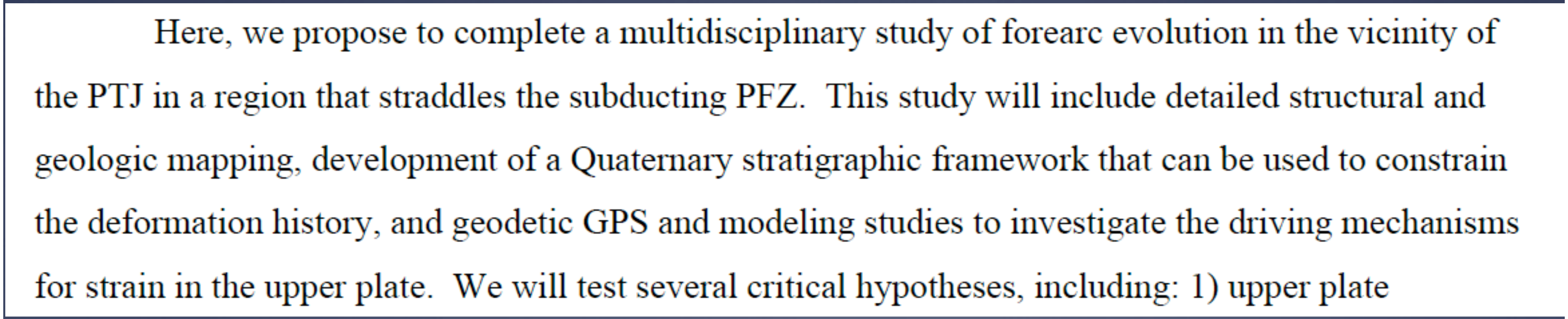
The methodology



Herein, we propose a study of the deformation, uplift, and erosion associated with the inner forearc of the Japan Trench. We will use a rich record of growth strata in Neogene to recent deposits along the coastal plain to evaluate tilting rates associated with fault-related folding at the seaward edge of the Abakuma massif. We will establish timing and rates of deformation at local sites along the fault by exploiting datable volcanic tephras interbedded with marine sediments. In both the Abakuma and Kitakami massifs, we will use low temperature thermochronometers to evaluate the timing and magnitude of erosional exhumation. Finally, we will exploit a well-preserved series of marine terraces to establish rates and patterns of rock uplift over late Pleistocene timescales.



Here, we propose to complete a multidisciplinary study of forearc evolution in the vicinity of the PTJ in a region that straddles the subducting PFZ. This study will include detailed structural and geologic mapping, development of a Quaternary stratigraphic framework that can be used to constrain the deformation history, and geodetic GPS and modeling studies to investigate the driving mechanisms for strain in the upper plate. We will test several critical hypotheses, including: 1) upper plate

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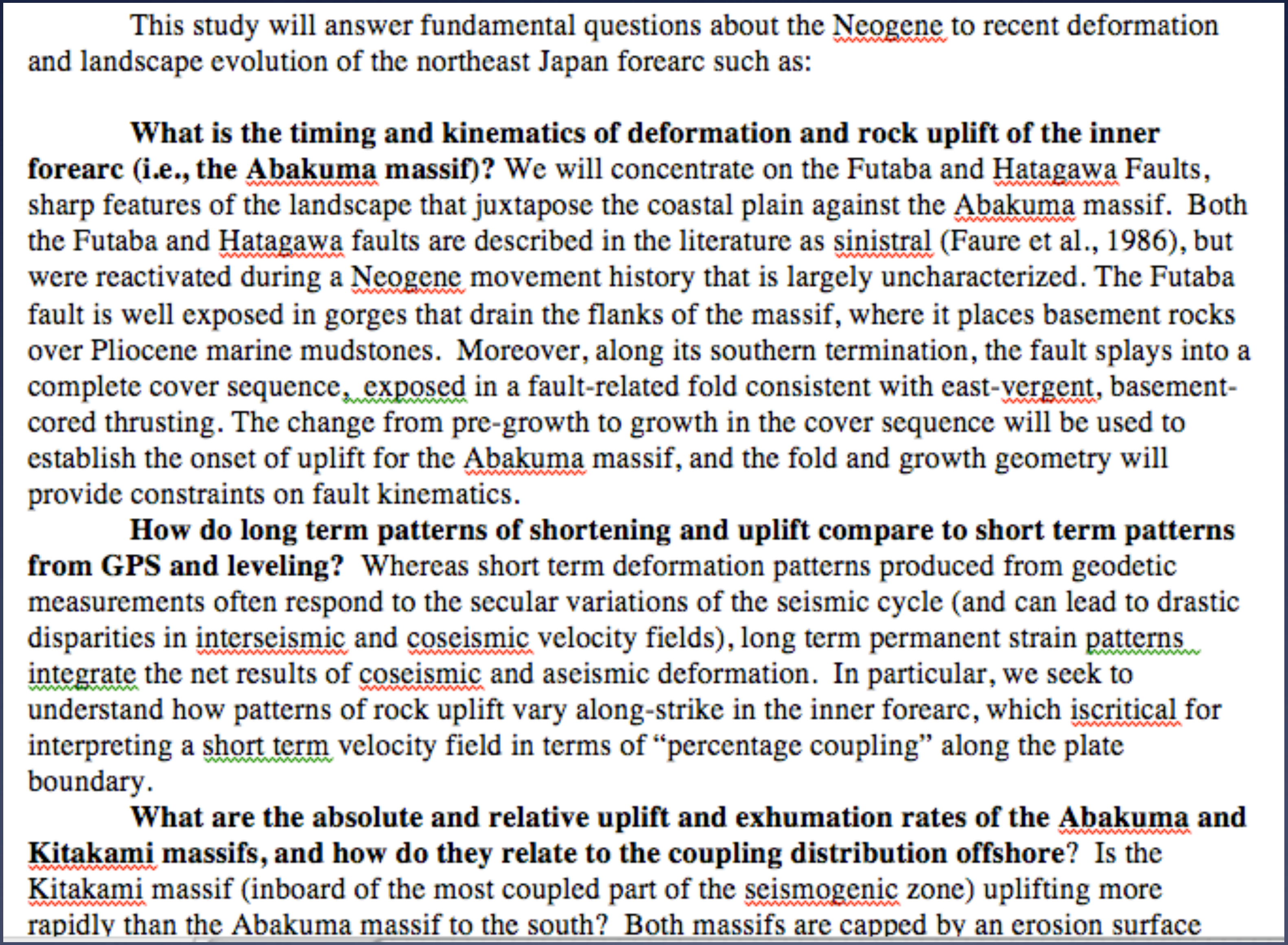
The Fundamental Questions



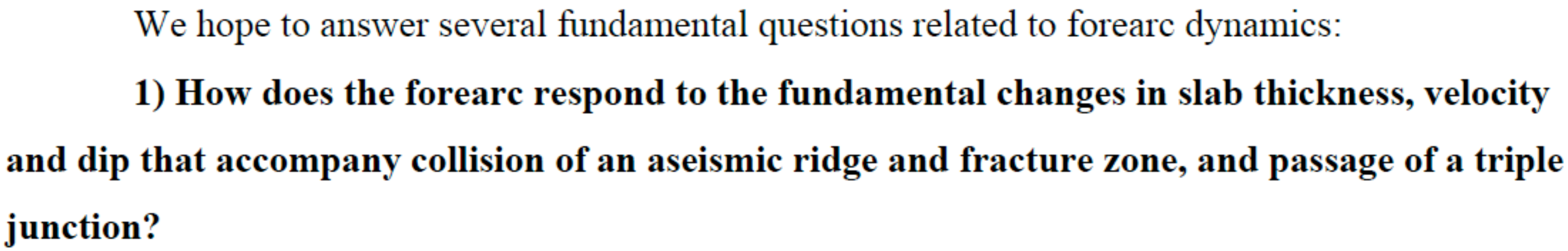
This study will answer fundamental questions about the Neogene to recent deformation and landscape evolution of the northeast Japan forearc such as:

What is the timing and kinematics of deformation and rock uplift of the inner forearc (i.e., the Abakuma massif)? We will concentrate on the Futaba and Hatagawa Faults, sharp features of the landscape that juxtapose the coastal plain against the Abakuma massif. Both the Futaba and Hatagawa faults are described in the literature as sinistral (Faure et al., 1986), but were reactivated during a Neogene movement history that is largely uncharacterized. The Futaba fault is well exposed in gorges that drain the flanks of the massif, where it places basement rocks over Pliocene marine mudstones. Moreover, along its southern termination, the fault splays into a complete cover sequence, exposed in a fault-related fold consistent with east-vergent, basement-cored thrusting. The change from pre-growth to growth in the cover sequence will be used to establish the onset of uplift for the Abakuma massif, and the fold and growth geometry will provide constraints on fault kinematics.

How do long term patterns of shortening and uplift compare to short term patterns from GPS and leveling? Whereas short term deformation patterns produced from geodetic measurements often respond to the secular variations of the seismic cycle (and can lead to drastic disparities in interseismic and coseismic velocity fields), long term permanent strain patterns integrate the net results of coseismic and aseismic deformation. In particular, we seek to understand how patterns of rock uplift vary along-strike in the inner forearc, which iscritical for interpreting a short term velocity field in terms of "percentage coupling" along the plate boundary.

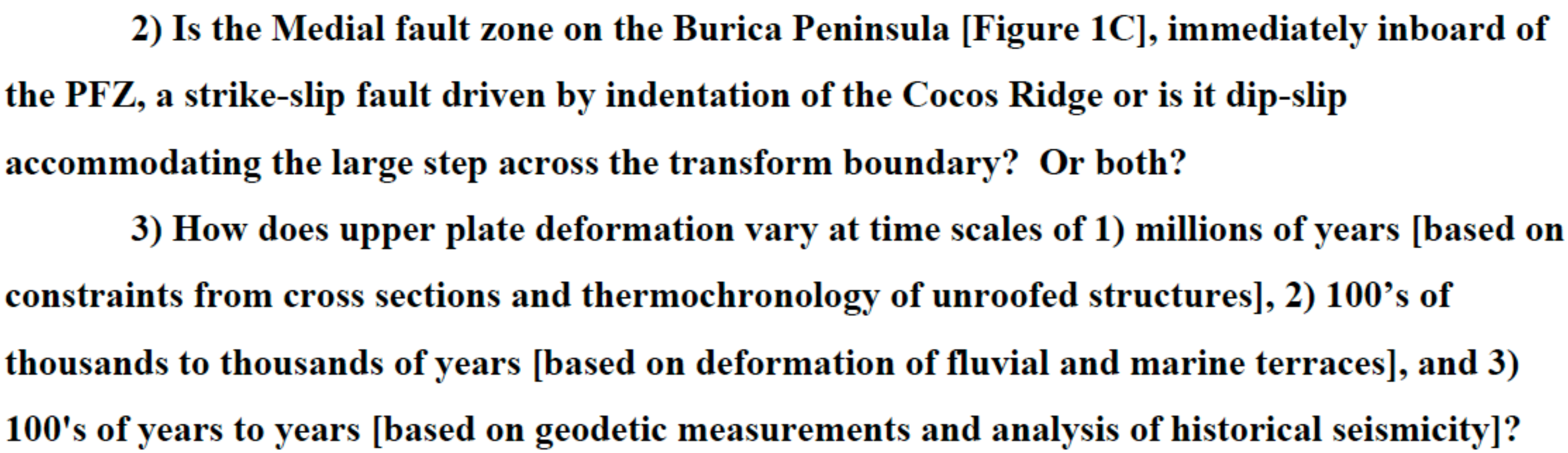
What are the absolute and relative uplift and exhumation rates of the Abakuma and Kitakami massifs, and how do they relate to the coupling distribution offshore? Is the Kitakami massif (inboard of the most coupled part of the seismogenic zone) uplifting more rapidly than the Abakuma massif to the south? Both massifs are capped by an erosion surface

The Fundamental Questions



We hope to answer several fundamental questions related to forearc dynamics:

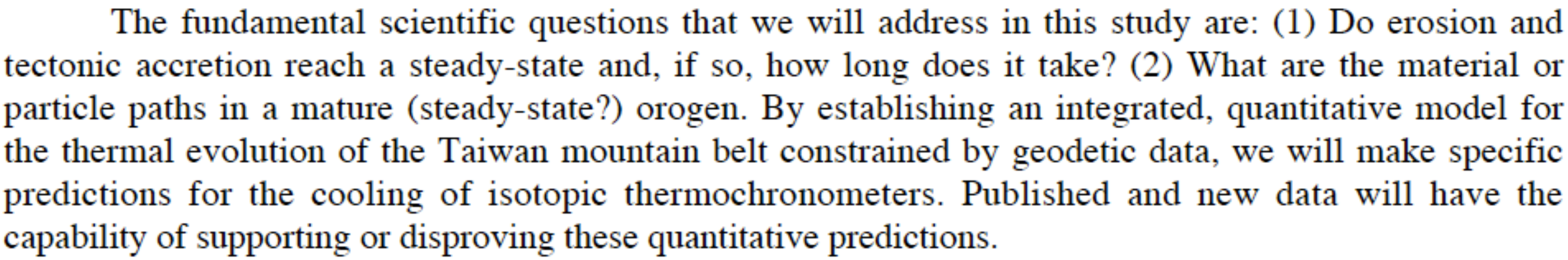
1) How does the forearc respond to the fundamental changes in slab thickness, velocity and dip that accompany collision of an aseismic ridge and fracture zone, and passage of a triple junction?



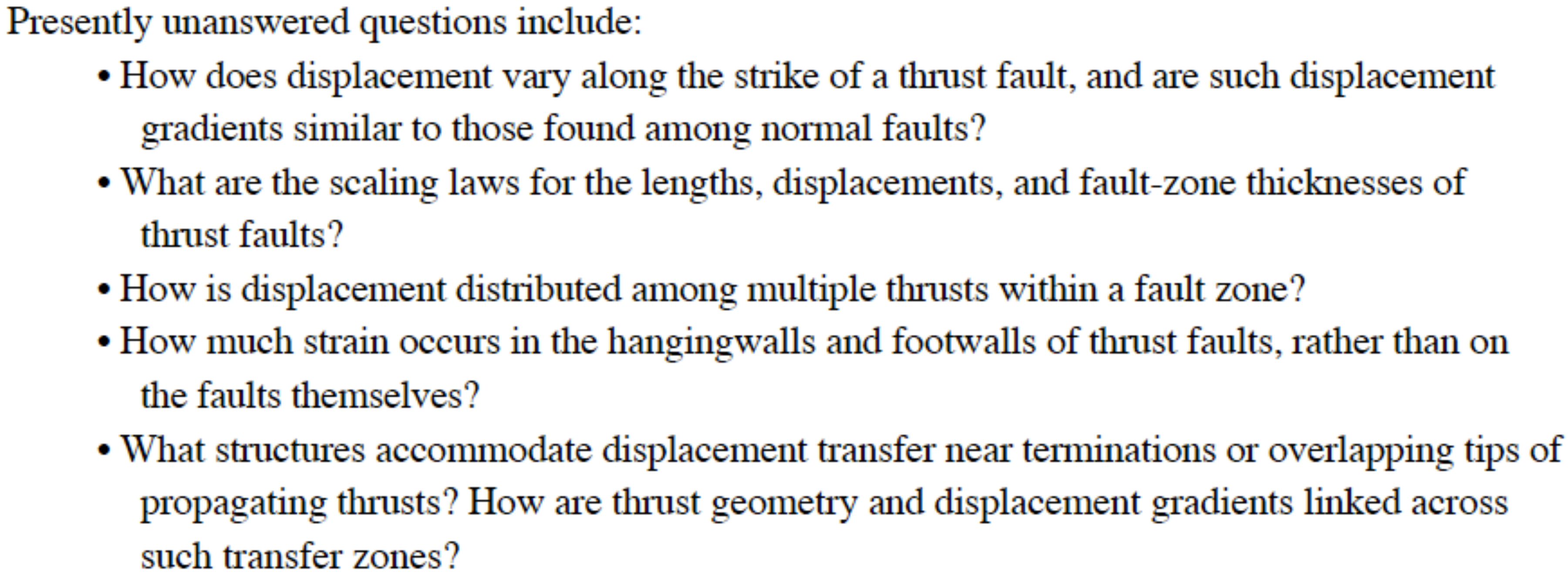
2) Is the Medial fault zone on the Burica Peninsula [Figure 1C], immediately inboard of the PFZ, a strike-slip fault driven by indentation of the Cocos Ridge or is it dip-slip accommodating the large step across the transform boundary? Or both?

3) How does upper plate deformation vary at time scales of 1) millions of years [based on constraints from cross sections and thermochronology of unroofed structures], 2) 100's of thousands to thousands of years [based on deformation of fluvial and marine terraces], and 3) 100's of years to years [based on geodetic measurements and analysis of historical seismicity]?

The Fundamental Questions



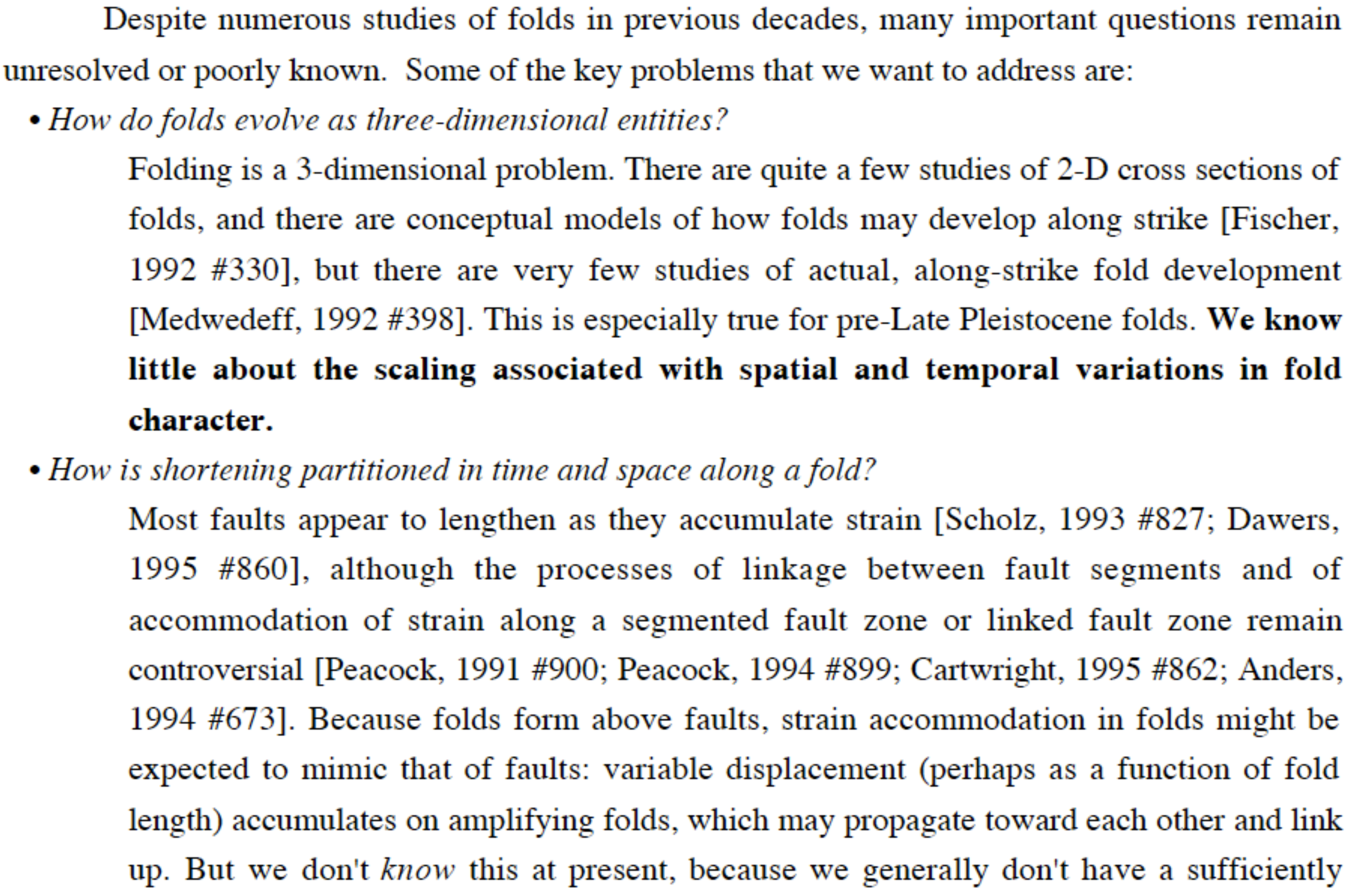
The fundamental scientific questions that we will address in this study are: (1) Do erosion and tectonic accretion reach a steady-state and, if so, how long does it take? (2) What are the material or particle paths in a mature (steady-state?) orogen. By establishing an integrated, quantitative model for the thermal evolution of the Taiwan mountain belt constrained by geodetic data, we will make specific predictions for the cooling of isotopic thermochronometers. Published and new data will have the capability of supporting or disproving these quantitative predictions.



Presently unanswered questions include:

- How does displacement vary along the strike of a thrust fault, and are such displacement gradients similar to those found among normal faults?
- What are the scaling laws for the lengths, displacements, and fault-zone thicknesses of thrust faults?
- How is displacement distributed among multiple thrusts within a fault zone?
- How much strain occurs in the hangingwalls and footwalls of thrust faults, rather than on the faults themselves?
- What structures accommodate displacement transfer near terminations or overlapping tips of propagating thrusts? How are thrust geometry and displacement gradients linked across such transfer zones?

The Fundamental Questions



Despite numerous studies of folds in previous decades, many important questions remain unresolved or poorly known. Some of the key problems that we want to address are:

- *How do folds evolve as three-dimensional entities?*

  Folding is a 3-dimensional problem. There are quite a few studies of 2-D cross sections of folds, and there are conceptual models of how folds may develop along strike [Fischer, 1992 #330], but there are very few studies of actual, along-strike fold development [Medwedeff, 1992 #398]. This is especially true for pre-Late Pleistocene folds. **We know little about the scaling associated with spatial and temporal variations in fold character.**

- *How is shortening partitioned in time and space along a fold?*

  Most faults appear to lengthen as they accumulate strain [Scholz, 1993 #827; Dawers, 1995 #860], although the processes of linkage between fault segments and of accommodation of strain along a segmented fault zone or linked fault zone remain controversial [Peacock, 1991 #900; Peacock, 1994 #899; Cartwright, 1995 #862; Anders, 1994 #673]. Because folds form above faults, strain accommodation in folds might be expected to mimic that of faults: variable displacement (perhaps as a function of fold length) accumulates on amplifying folds, which may propagate toward each other and link up. But we don't *know* this at present, because we generally don't have a sufficiently

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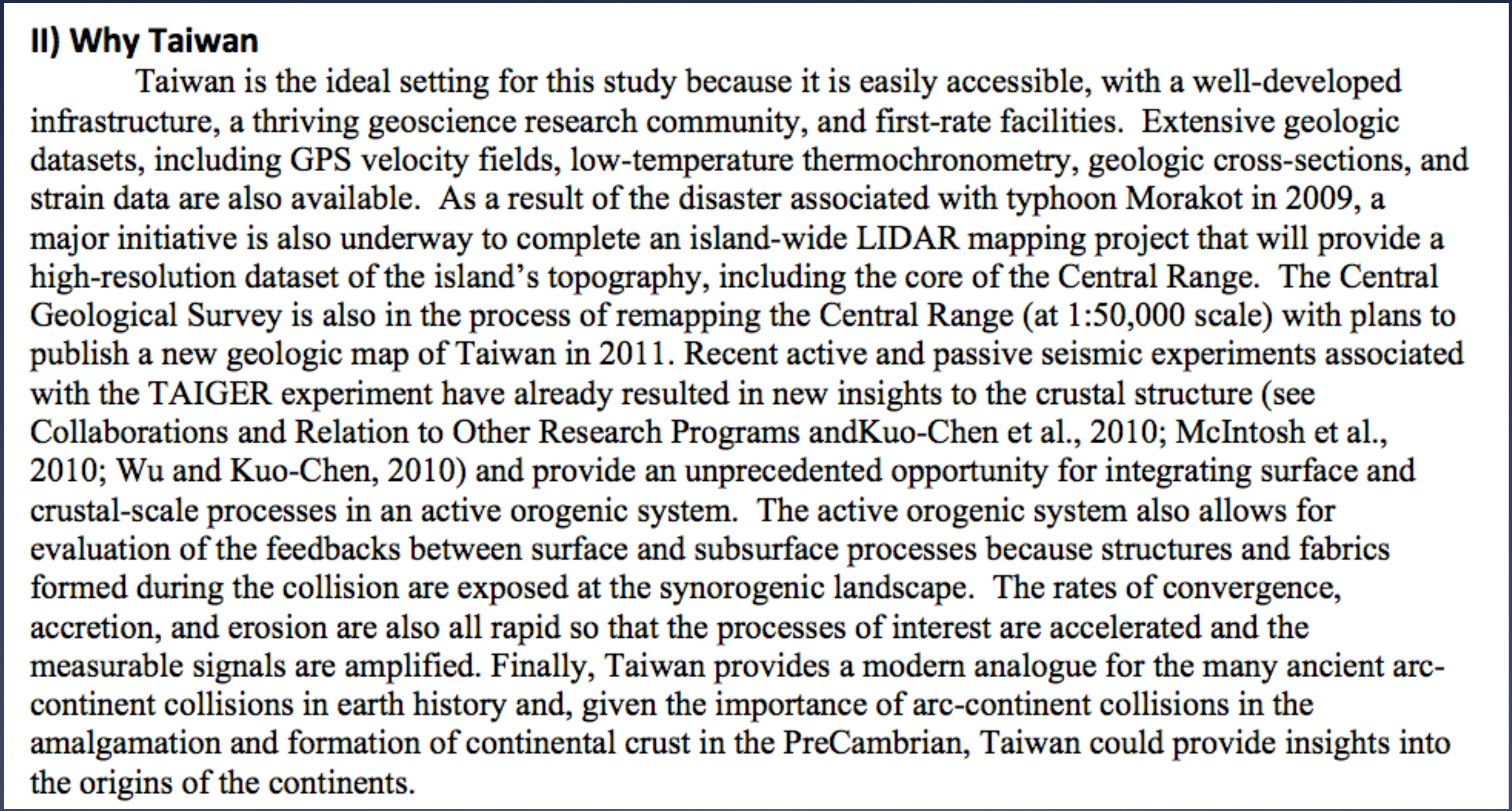
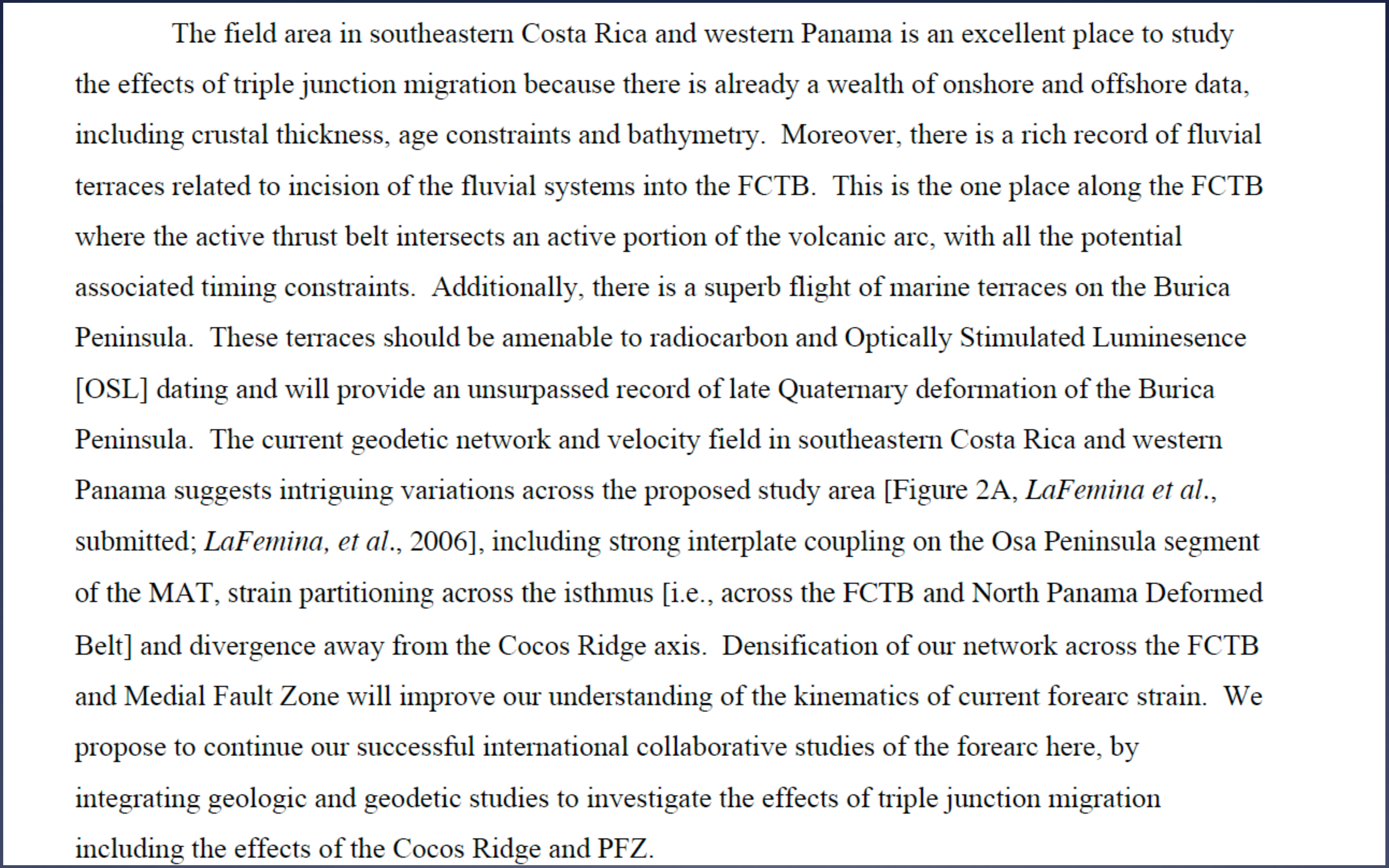
Why the best place in the world (or the obvious next step)



II) Why Taiwan

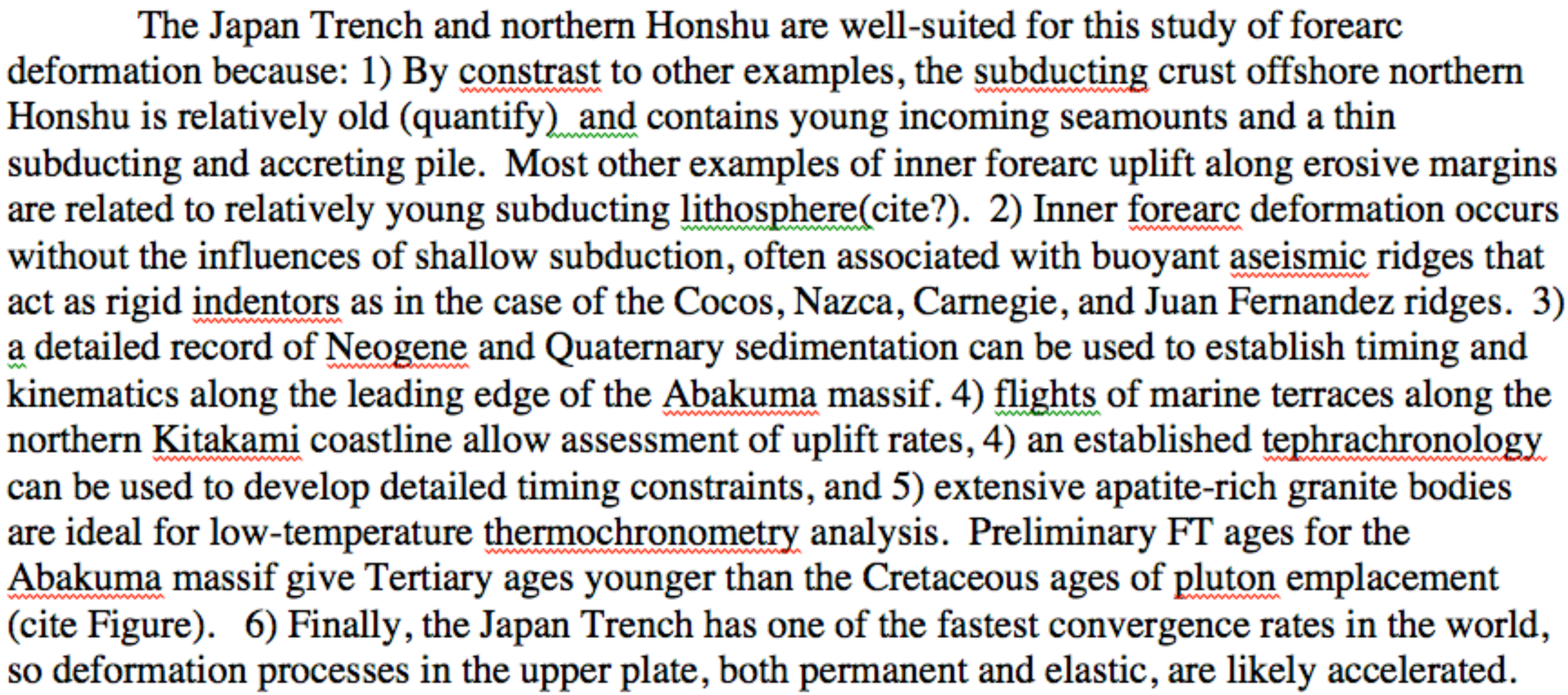
Taiwan is the ideal setting for this study because it is easily accessible, with a well-developed infrastructure, a thriving geoscience research community, and first-rate facilities. Extensive geologic datasets, including GPS velocity fields, low-temperature thermochronometry, geologic cross-sections, and strain data are also available. As a result of the disaster associated with typhoon Morakot in 2009, a major initiative is also underway to complete an island-wide LIDAR mapping project that will provide a high-resolution dataset of the island's topography, including the core of the Central Range. The Central Geological Survey is also in the process of remapping the Central Range (at 1:50,000 scale) with plans to publish a new geologic map of Taiwan in 2011. Recent active and passive seismic experiments associated with the TAIGER experiment have already resulted in new insights to the crustal structure (see Collaborations and Relation to Other Research Programs andKuo-Chen et al., 2010; McIntosh et al., 2010; Wu and Kuo-Chen, 2010) and provide an unprecedented opportunity for integrating surface and crustal-scale processes in an active orogenic system. The active orogenic system also allows for evaluation of the feedbacks between surface and subsurface processes because structures and fabrics formed during the collision are exposed at the synorogenic landscape. The rates of convergence, accretion, and erosion are also all rapid so that the processes of interest are accelerated and the measurable signals are amplified. Finally, Taiwan provides a modern analogue for the many ancient arc-continent collisions in earth history and, given the importance of arc-continent collisions in the amalgamation and formation of continental crust in the PreCambrian, Taiwan could provide insights into the origins of the continents.

Why the best place in the world (or the obvious next step)



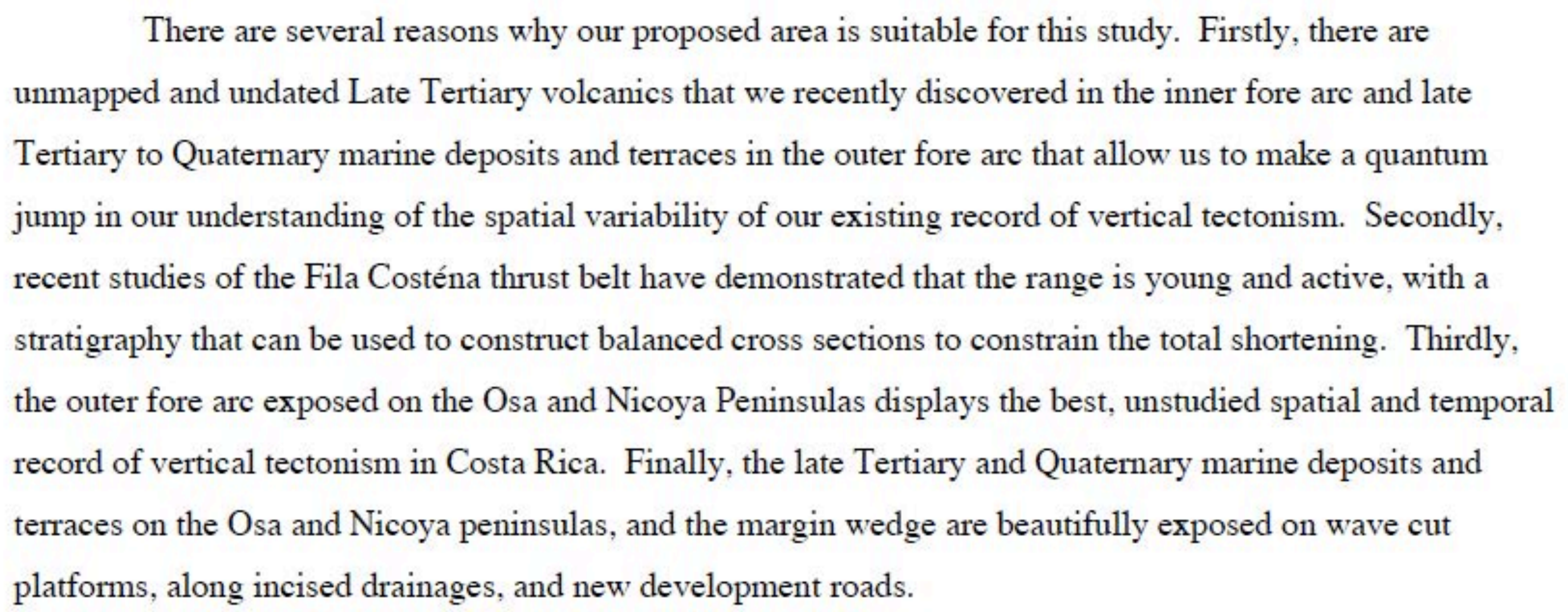
The field area in southeastern Costa Rica and western Panama is an excellent place to study the effects of triple junction migration because there is already a wealth of onshore and offshore data, including crustal thickness, age constraints and bathymetry. Moreover, there is a rich record of fluvial terraces related to incision of the fluvial systems into the FCTB. This is the one place along the FCTB where the active thrust belt intersects an active portion of the volcanic arc, with all the potential associated timing constraints. Additionally, there is a superb flight of marine terraces on the Burica Peninsula. These terraces should be amenable to radiocarbon and Optically Stimulated Luminesence [OSL] dating and will provide an unsurpassed record of late Quaternary deformation of the Burica Peninsula. The current geodetic network and velocity field in southeastern Costa Rica and western Panama suggests intriguing variations across the proposed study area [Figure 2A, *LaFemina et al.*, submitted; *LaFemina, et al.*, 2006], including strong interplate coupling on the Osa Peninsula segment of the MAT, strain partitioning across the isthmus [i.e., across the FCTB and North Panama Deformed Belt] and divergence away from the Cocos Ridge axis. Densification of our network across the FCTB and Medial Fault Zone will improve our understanding of the kinematics of current forearc strain. We propose to continue our successful international collaborative studies of the forearc here, by integrating geologic and geodetic studies to investigate the effects of triple junction migration including the effects of the Cocos Ridge and PFZ.

Why the best place in the world (or the obvious next step)



The Japan Trench and northern Honshu are well-suited for this study of forearc deformation because: 1) By constrast to other examples, the subducting crust offshore northern Honshu is relatively old (quantify) and contains young incoming seamounts and a thin subducting and accreting pile. Most other examples of inner forearc uplift along erosive margins are related to relatively young subducting lithosphere(cite?). 2) Inner forearc deformation occurs without the influences of shallow subduction, often associated with buoyant aseismic ridges that act as rigid indentors as in the case of the Cocos, Nazca, Carnegie, and Juan Fernandez ridges. 3) a detailed record of Neogene and Quaternary sedimentation can be used to establish timing and kinematics along the leading edge of the Abakuma massif. 4) flights of marine terraces along the northern Kitakami coastline allow assessment of uplift rates, 4) an established tephrachronology can be used to develop detailed timing constraints, and 5) extensive apatite-rich granite bodies are ideal for low-temperature thermochronometry analysis. Preliminary FT ages for the Abakuma massif give Tertiary ages younger than the Cretaceous ages of pluton emplacement (cite Figure). 6) Finally, the Japan Trench has one of the fastest convergence rates in the world, so deformation processes in the upper plate, both permanent and elastic, are likely accelerated.

Why the best place in the world (or the obvious next step)



There are several reasons why our proposed area is suitable for this study. Firstly, there are unmapped and undated Late Tertiary volcanics that we recently discovered in the inner fore arc and late Tertiary to Quaternary marine deposits and terraces in the outer fore arc that allow us to make a quantum jump in our understanding of the spatial variability of our existing record of vertical tectonism. Secondly, recent studies of the Fila Costéna thrust belt have demonstrated that the range is young and active, with a stratigraphy that can be used to construct balanced cross sections to constrain the total shortening. Thirdly, the outer fore arc exposed on the Osa and Nicoya Peninsulas displays the best, unstudied spatial and temporal record of vertical tectonism in Costa Rica. Finally, the late Tertiary and Quaternary marine deposits and terraces on the Osa and Nicoya peninsulas, and the margin wedge are beautifully exposed on wave cut platforms, along incised drainages, and new development roads.

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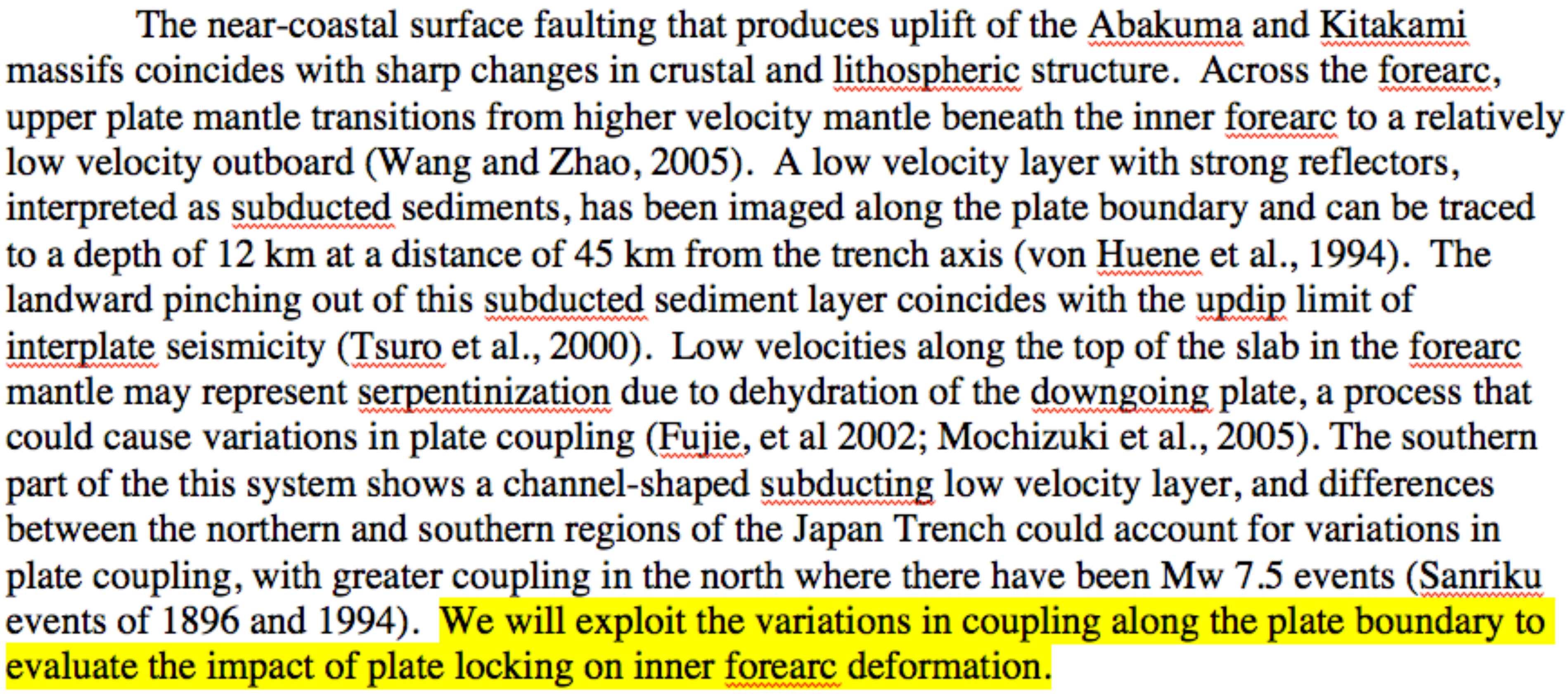
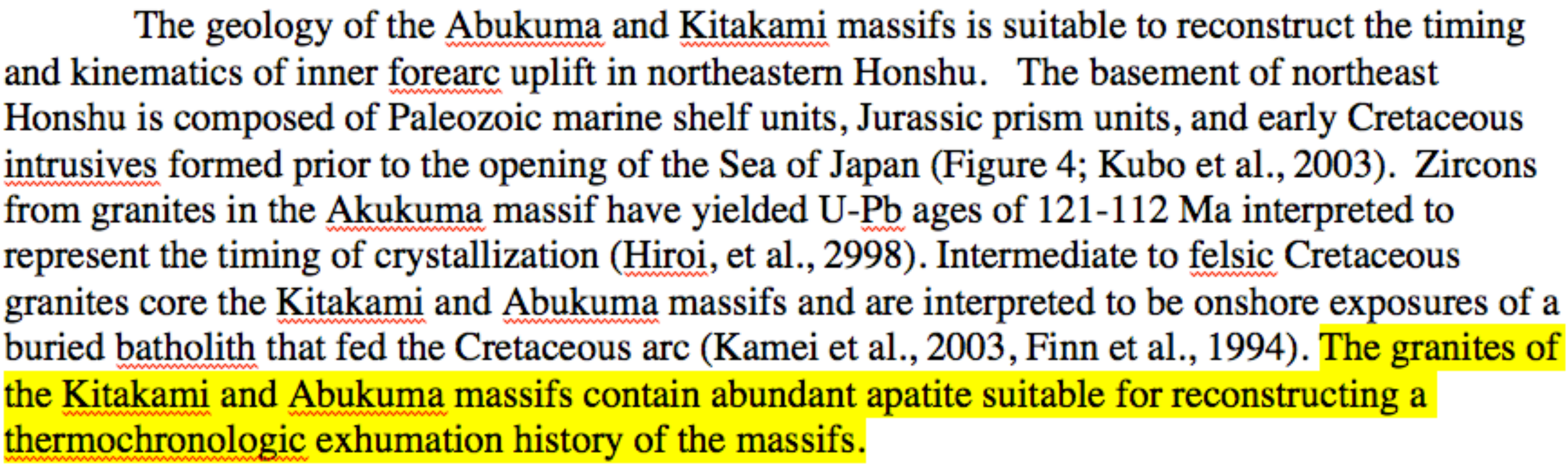
Background



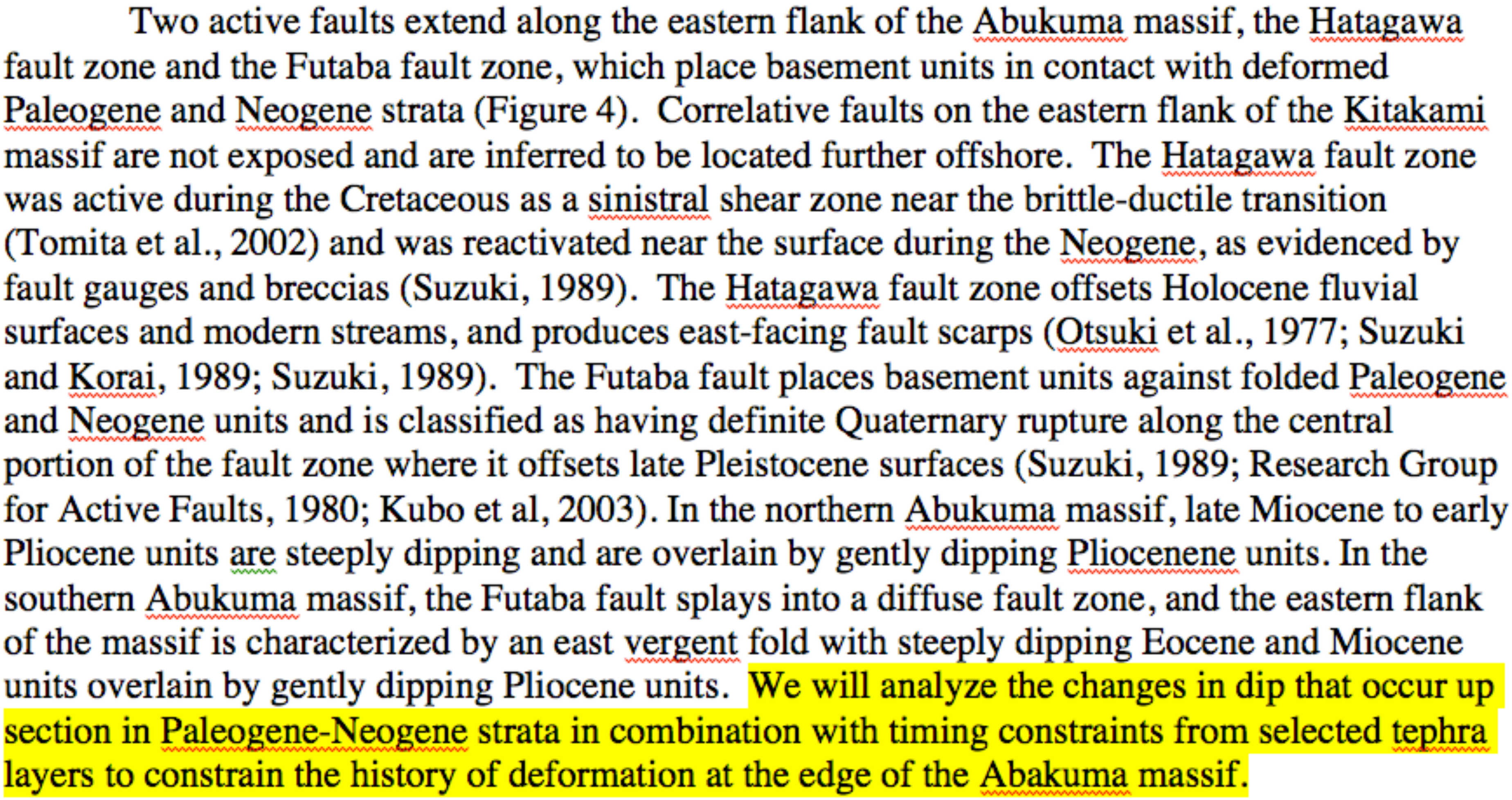
The near-coastal surface faulting that produces uplift of the Abakuma and Kitakami massifs coincides with sharp changes in crustal and lithospheric structure. Across the forearc, upper plate mantle transitions from higher velocity mantle beneath the inner forearc to a relatively low velocity outboard (Wang and Zhao, 2005). A low velocity layer with strong reflectors, interpreted as subducted sediments, has been imaged along the plate boundary and can be traced to a depth of 12 km at a distance of 45 km from the trench axis (von Huene et al., 1994). The landward pinching out of this subducted sediment layer coincides with the updip limit of interplate seismicity (Tsuro et al., 2000). Low velocities along the top of the slab in the forearc mantle may represent serpentinization due to dehydration of the downgoing plate, a process that could cause variations in plate coupling (Fujie, et al 2002; Mochizuki et al., 2005). The southern part of the this system shows a channel-shaped subducting low velocity layer, and differences between the northern and southern regions of the Japan Trench could account for variations in plate coupling, with greater coupling in the north where there have been Mw 7.5 events (Sanriku events of 1896 and 1994). We will exploit the variations in coupling along the plate boundary to evaluate the impact of plate locking on inner forearc deformation.

Background



The geology of the Abukuma and Kitakami massifs is suitable to reconstruct the timing and kinematics of inner forearc uplift in northeastern Honshu. The basement of northeast Honshu is composed of Paleozoic marine shelf units, Jurassic prism units, and early Cretaceous intrusives formed prior to the opening of the Sea of Japan (Figure 4; Kubo et al., 2003). Zircons from granites in the Akukuma massif have yielded U-Pb ages of 121-112 Ma interpreted to represent the timing of crystallization (Hiroi, et al., 2998). Intermediate to felsic Cretaceous granites core the Kitakami and Abukuma massifs and are interpreted to be onshore exposures of a buried batholith that fed the Cretaceous arc (Kamei et al., 2003, Finn et al., 1994). The granites of the Kitakami and Abukuma massifs contain abundant apatite suitable for reconstructing a thermochronologic exhumation history of the massifs.

Background



Two active faults extend along the eastern flank of the Abukuma massif, the Hatagawa fault zone and the Futaba fault zone, which place basement units in contact with deformed Paleogene and Neogene strata (Figure 4). Correlative faults on the eastern flank of the Kitakami massif are not exposed and are inferred to be located further offshore. The Hatagawa fault zone was active during the Cretaceous as a sinistral shear zone near the brittle-ductile transition (Tomita et al., 2002) and was reactivated near the surface during the Neogene, as evidenced by fault gauges and breccias (Suzuki, 1989). The Hatagawa fault zone offsets Holocene fluvial surfaces and modern streams, and produces east-facing fault scarps (Otsuki et al., 1977; Suzuki and Korai, 1989; Suzuki, 1989). The Futaba fault places basement units against folded Paleogene and Neogene units and is classified as having definite Quaternary rupture along the central portion of the fault zone where it offsets late Pleistocene surfaces (Suzuki, 1989; Research Group for Active Faults, 1980; Kubo et al, 2003). In the northern Abukuma massif, late Miocene to early Pliocene units are steeply dipping and are overlain by gently dipping Pliocenene units. In the southern Abukuma massif, the Futaba fault splays into a diffuse fault zone, and the eastern flank of the massif is characterized by an east vergent fold with steeply dipping Eocene and Miocene units overlain by gently dipping Pliocene units. We will analyze the changes in dip that occur up section in Paleogene-Neogene strata in combination with timing constraints from selected tephra layers to constrain the history of deformation at the edge of the Abakuma massif.

Panel Review: Things to avoid

- “Bag shaking”
- “Disconnect between the Hypothesis and the data”
- “Fails the ‘So What?’ factor”
- “Great person” reviews
- “Vague outcome” (a better understanding or insight into)
- “Not built around a transportable idea”

The Silver Bullet

Broader Impacts

Project Summary

Data Management Plan

Budget Justification

A philosophical question

Does a fixation on “the Scientific Method” lead to “safe science” and prevent funding for “transformative science”?