Source-to-Sink Sediment Delivery in the Gulf of Papua from SEM-MLA-aided Provenance and Textural Analysis of Turbidite Sands*

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Abstract

Provenance of Pleistocene-Holocene deepwater sediments in the Gulf of Papua (NSF Source-to-Sink Focus Area) has been studied to understand glacio-eustatic influences on sedimentary routing, and to develop a modern analog of dynamic processes controlling sediment sources and delivery. Turbidities were sampled in seven jumbo piston cores from the slope and basin floor, yielding 53 sand samples. A quantitative detrital compositional analysis was conducted using scanning electron microscopy (SEM) and mineral liberation analysis (MLA) of ~15,000 individual grains per sample, with a minimum grain diameter limit of 3.9 µm. Tests using the Gazzi-Dickinson ternary diagram show a lack of differentiation among samples. Although free from grain-size effects, use of this diagram is strongly affected by the detailed mineralogical classification that results from automated MLA. MLA allows identification of multiple mineral grains within larger particles, which, with felsic minerals, tends to increase the quantity of monocrystalline quartz over standard manual methods, shifting plots into more quartz and feldspar rich fields. MLA does allow sample differentiation using mafic/felsic ratios, and content of pumice and heavy minerals.

Time-sliced provenance based on our C-14 age model shows three major pathways: (1) long-distance NW-SE sediment transport of quartzo-feldspathic sand sourced from the Papuan Mainland, delivered from the Fly-Strickland fluvial system through Pandora shelf and slope (core MV-54), Pandora basin floor (cores MV-23, 33) and Moresby Channel (MV-25, 29); (2) short-distance transport of felsic-mafic volcanic sand apparently from the collision margin of the Papuan Peninsula, delivered via small rivers narrow shelf, and deep-sea canyons (MV-22); and (3) intermediate-distance delivery from the Fly-Strickland and Papuan Peninsula along coastal pathways to the Moresby Trough (MV-22). The vertical provenance pattern shows that the Pandora Trough samples (MV 23, 33, 54) were entirely pathway 1 during the time period 44-17 Ka, while Moresby Trough received sediment via pathway 1 (MV-25, 29) and

pathway 2 (MV-22), gradually shifting to pathway 3 from late Pleistocene to the middle Holocene. We also suggest that the Gazzi Dickinson scheme be re-evaluated in light of powerful new automated MLA techniques, to allow better sample discrimination in fine-grained lithic and felsic sands typical of our study area, and many other deep-water depocenters.

Source to Sink sediment delivery in the Gulf of Papua from SEM-MLA aided provenance analysis of Turbidite Sands

MEMORIAL UNIVERSITY

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS AAPG 1917

Erlangga Septama[1], Samuel J. Bentley[2] and Michael Shaffer[1]

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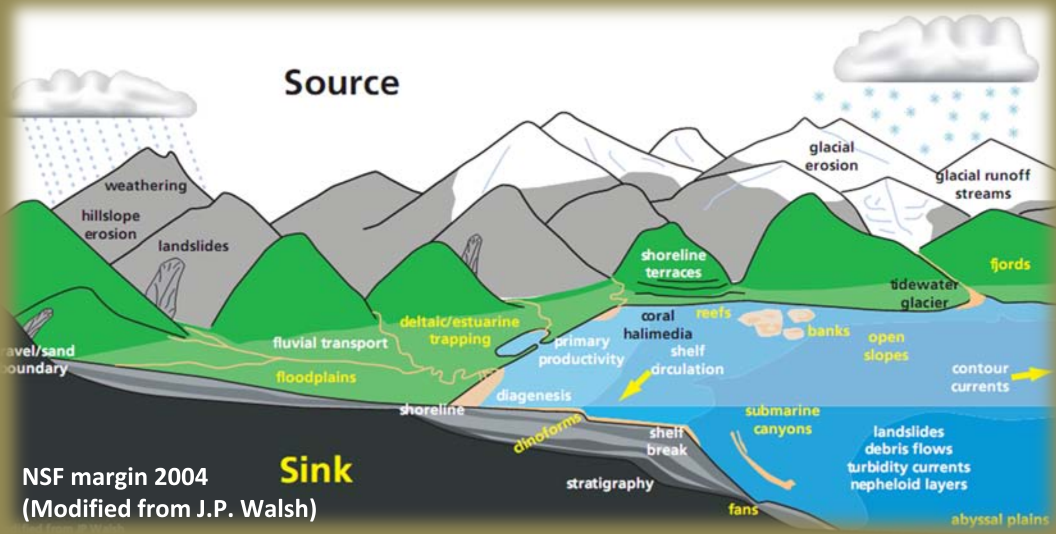
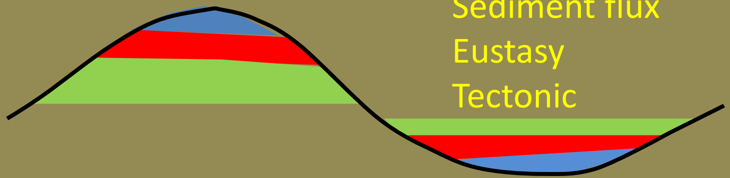
S2S system :

why does it matter ?

- Approach focuses on both marine and terrestrial processes

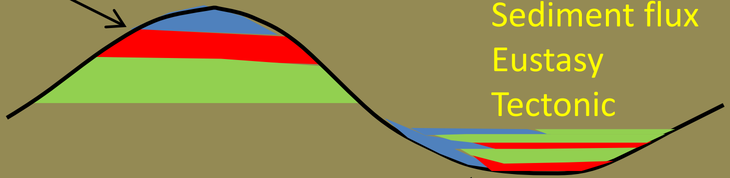


NSF margin 2004
(Modified from J.P. Walsh)



Time
Sediment flux
Eustasy
Tectonic

Minerals hydraulic behavior
Rocks erosional resistance
Paleo-climate
Morphology modification



Time
Sediment flux
Eustasy
Tectonic

Dispersal trend
Residence time
Oceanographic effect
Seafloor morphology

Prediction of :

Dispersal pattern & geometry

Reservoir quality

A Quick Perspective

- NSF Focus Area, 2004
- Sediment input 200 MT/year
- Negligible Anthropogenic effect

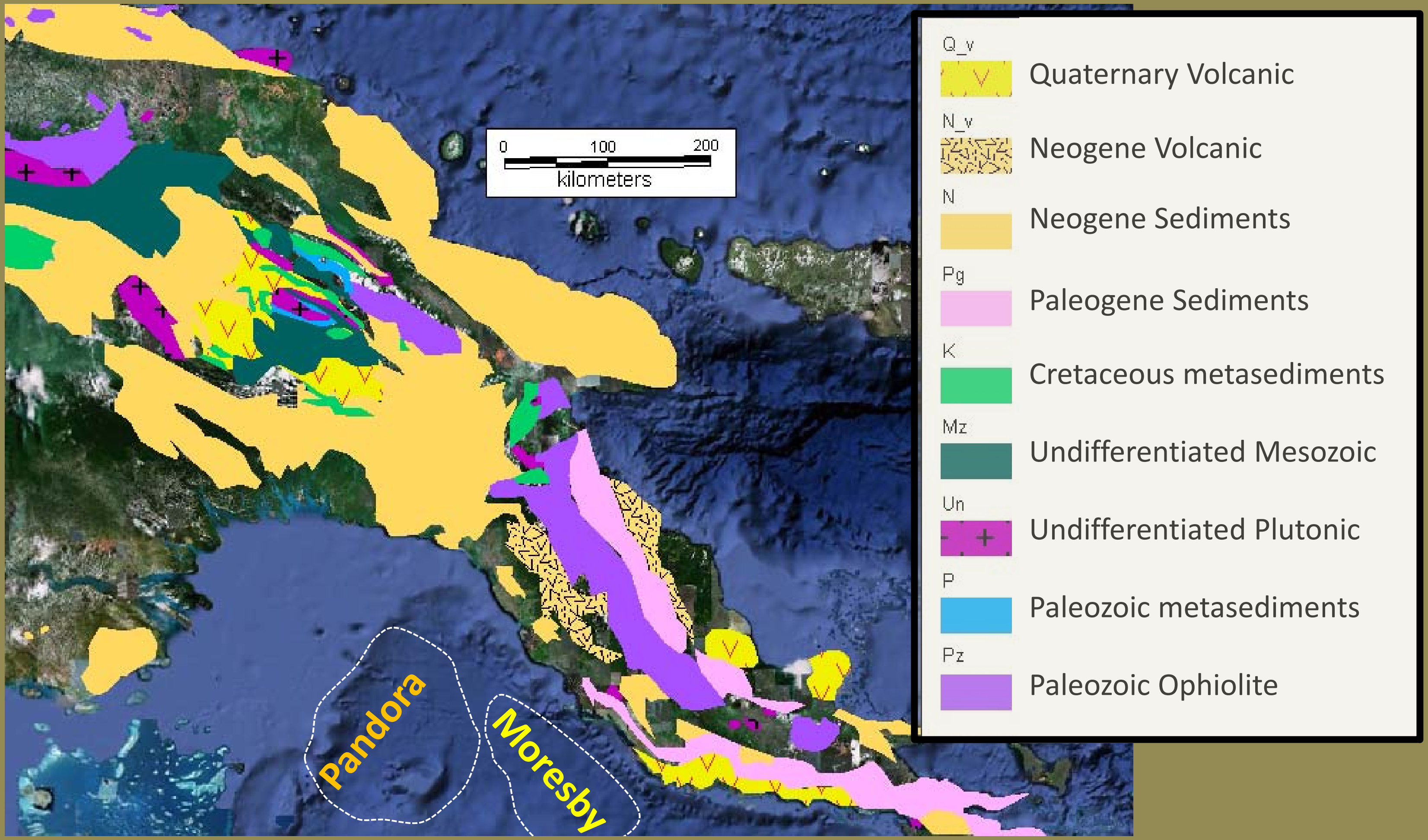
Contrast Shelf Setting Pandora Vs. Moresby

Source?, **timing?** & **routing?**

What **factors** are influencing the processes ?

How do the processes build the stratigraphy record ??

Septama & Bentley, 2011



Geological Map from USGS open file report o/w Google Map)

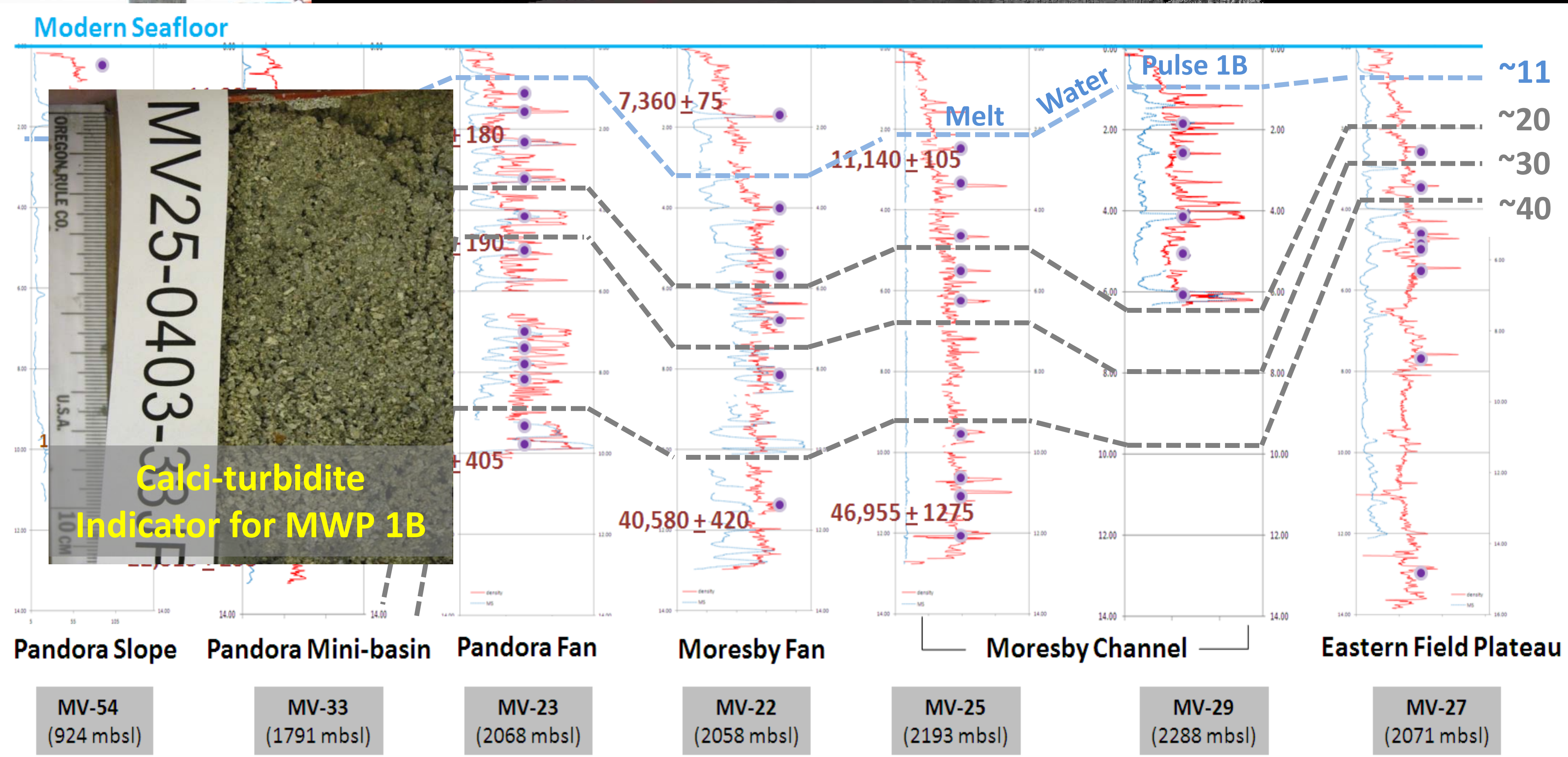
Source

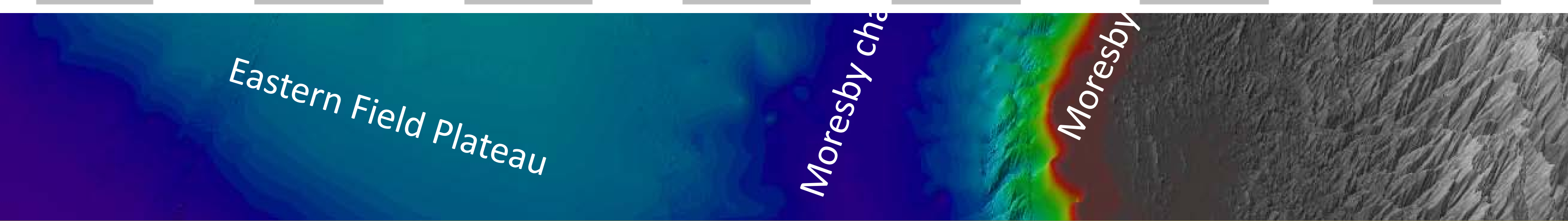
Pandora = texturally mature sediment from Fly-Strickland

(large input of Neogene sediment from Kikori-Purari, and volcanic from fly highland)

Moresby = Short transport, additional metamorphic & mafic-ultramafic input

Jumbo Piston core (9 -14 m)
Melville 2004 cruise

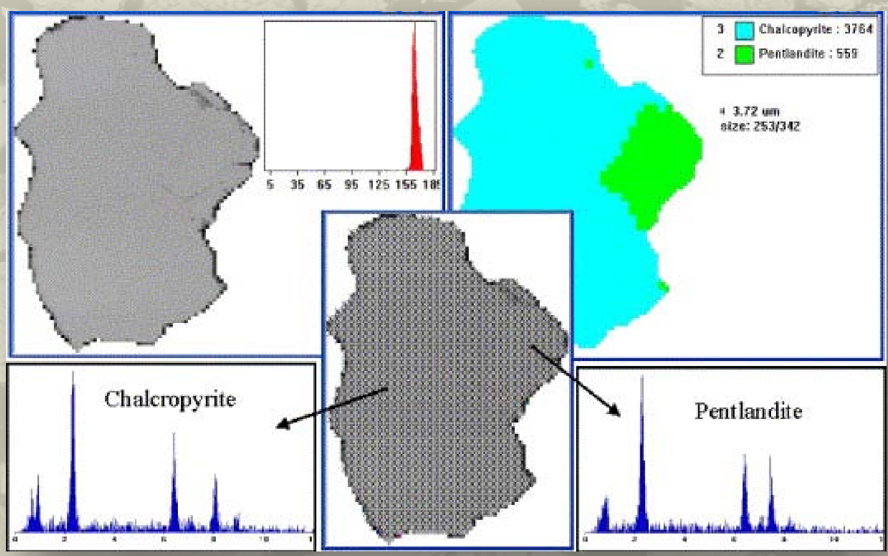


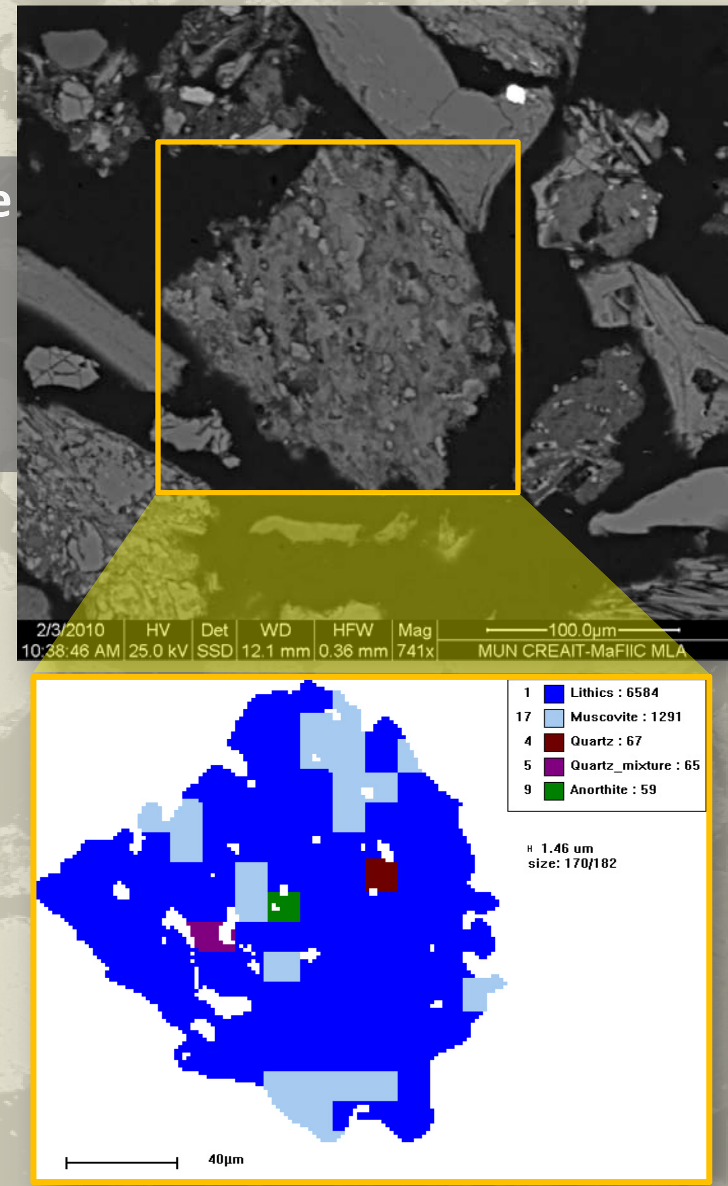


SEM-MLA Analysis

(Scanned Electron Microscopy – Mineral Liberation Analysis)

- Collecting backscatter electrons from grain surface
- Match mineral density through spectral library
- Classify minerals using MLA
- Allows **50-80,000** grain count





Pandora vs. Moresby
How to identify the signal?

a. Direct modal mineralogy approach :

Sensitive heavy minerals ratio

Comparative bar

Detrital Feldspar

a+b = S2S narrative

→ **Provenance character**

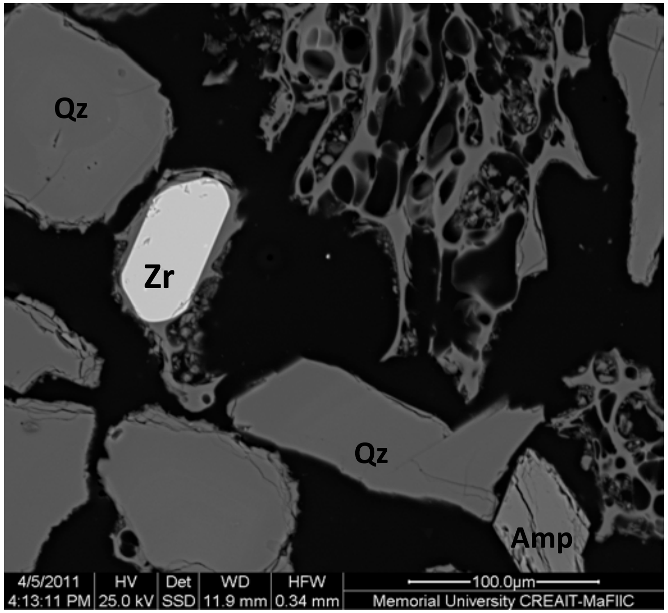
b. Multivariate analysis approach :

Non Metric Dimensional Scaling analysis (n-MDS)

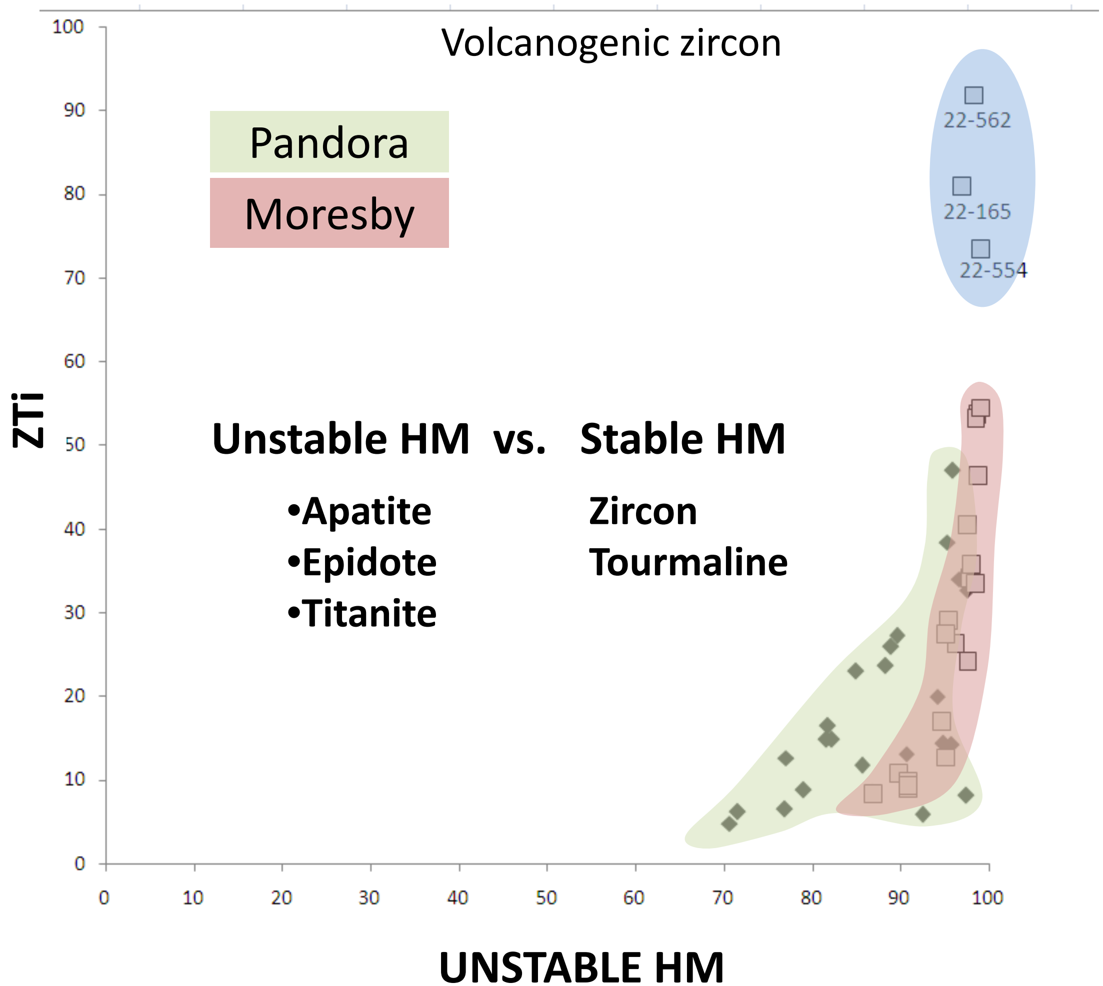
Principal Component Analysis

→ **Mineral assemblage**

Environmental Trends



Sensitive Heavy Minerals Ratio

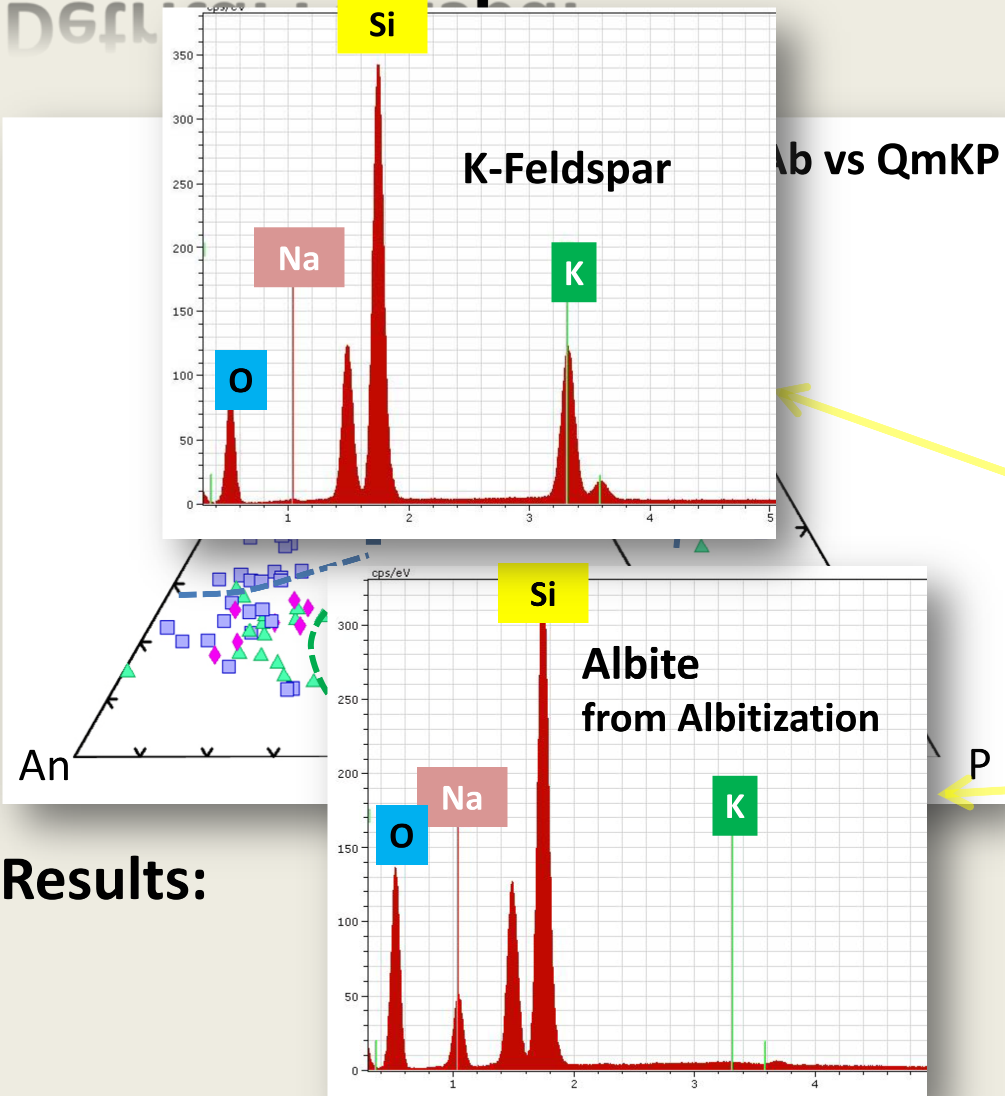


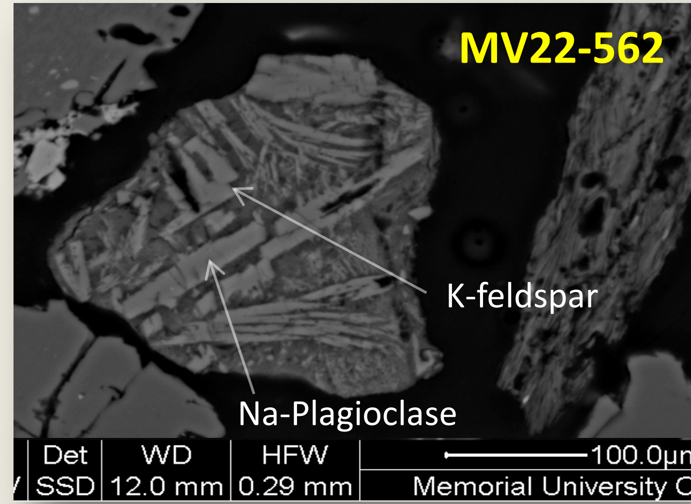
Prolonged transport in Pandora

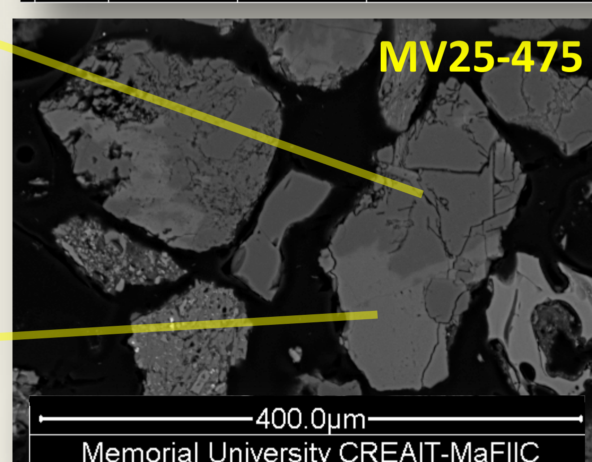
Unstable→ Fresh source → Rapid unroofing in Moresby

Zircon in Moresby Trough is Volcanogenic

Detrital Feldspar



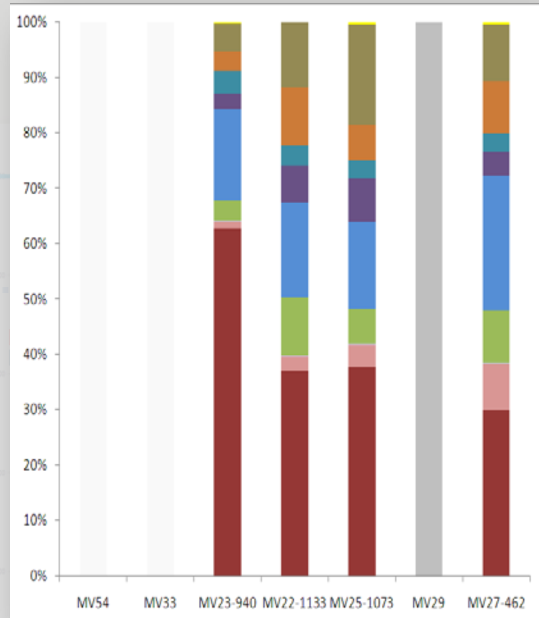




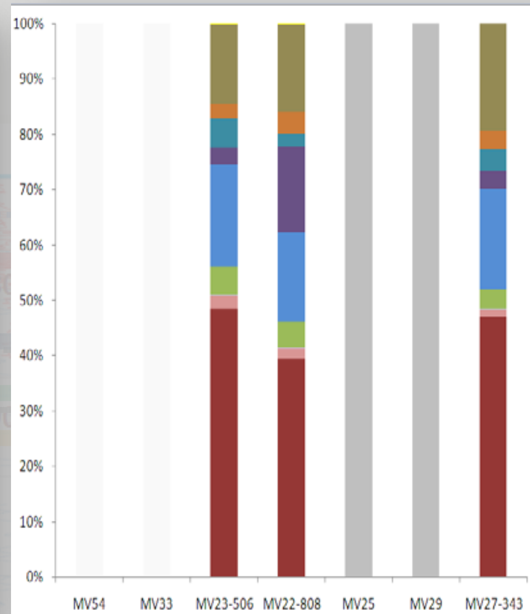
Results:

Higher K-spar and Na-plag in Moresby Trough from volcanic source

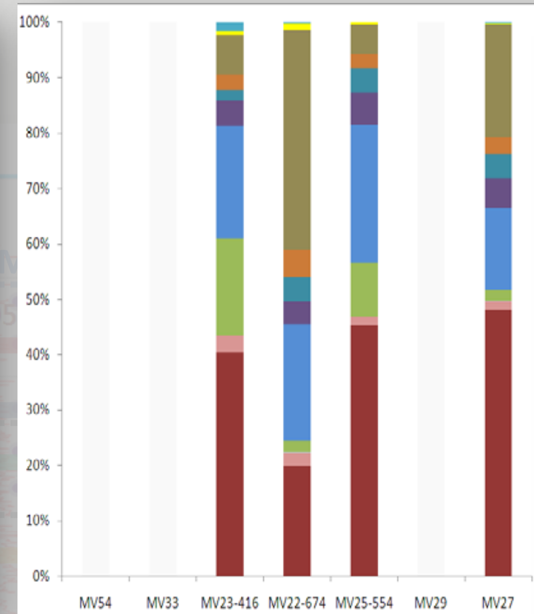
Authigenic Albite in Moresby Trough = Metamorphic Source



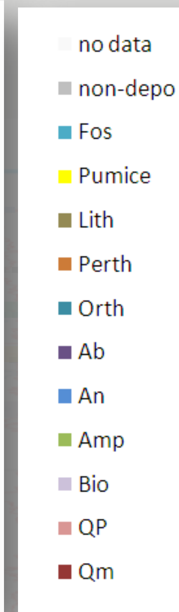
Time slice 1 (~ 42 Ka)

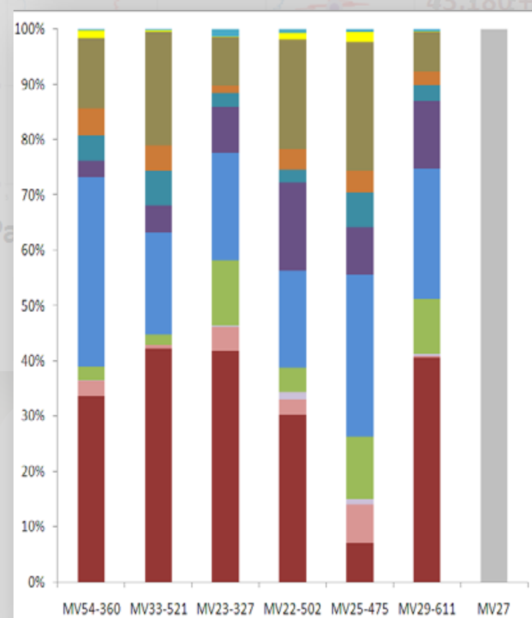


Time slice 2 (~ 32 Ka)

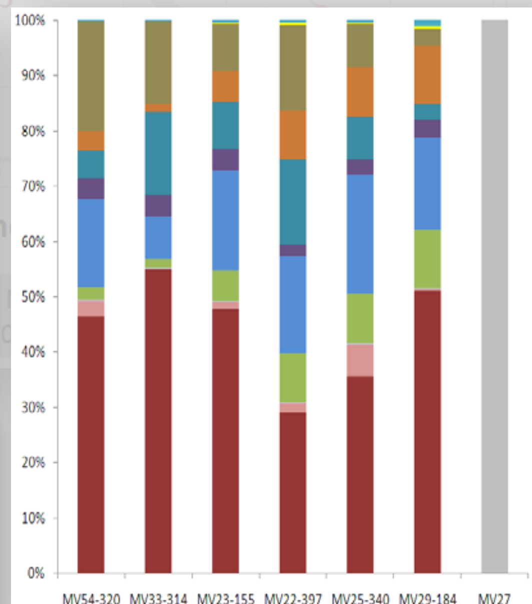


Time slice 3 (22 – 26 Ka)





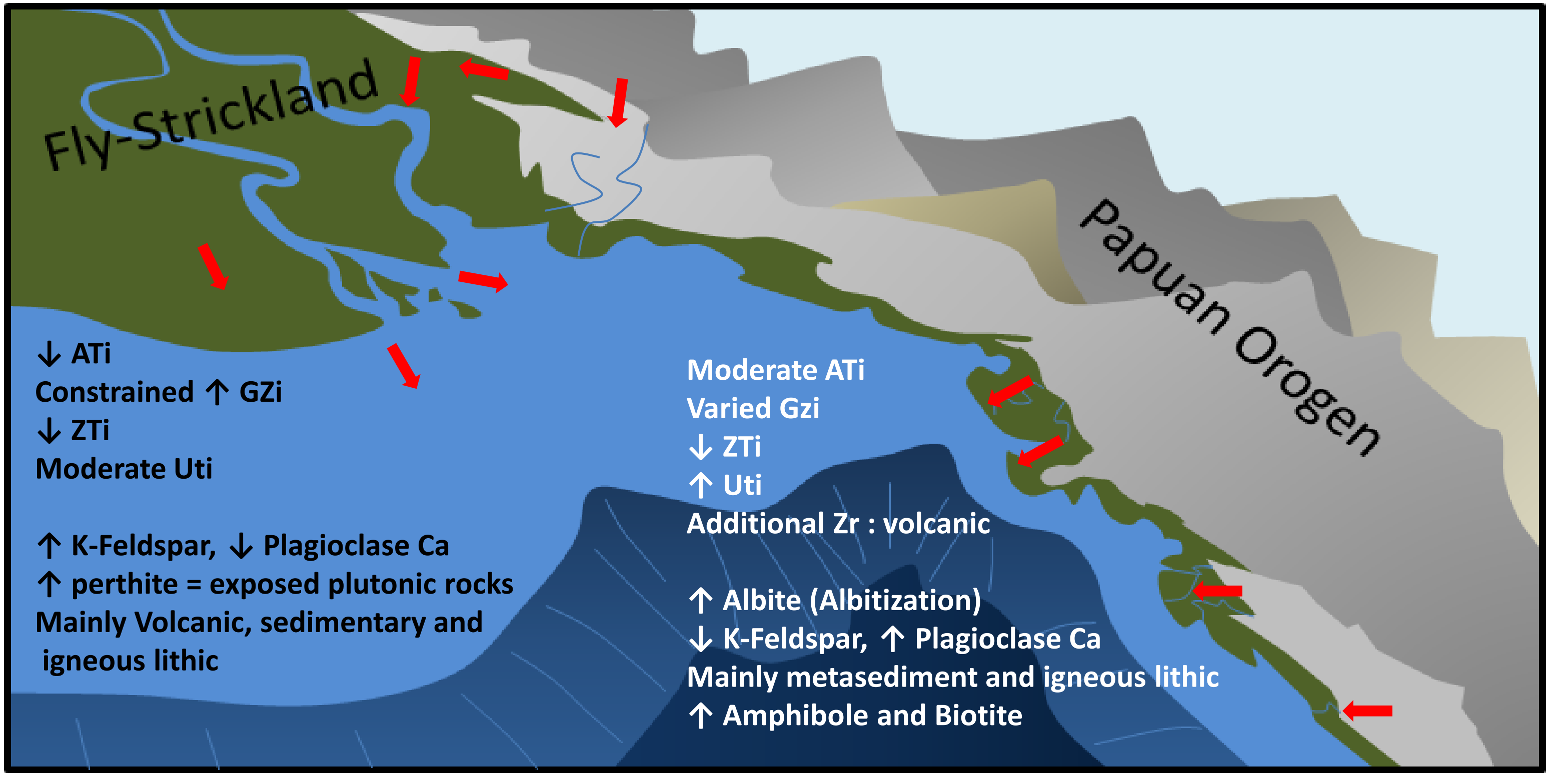
Time slice 4a (20 – 17 Ka)



Time slice 4b (15 – 12 Ka)

Mineralogy variation through time

Provenance Characterization, Pandora vs. Moresby Troughs



Major input for both troughs are from Papuan Orogen

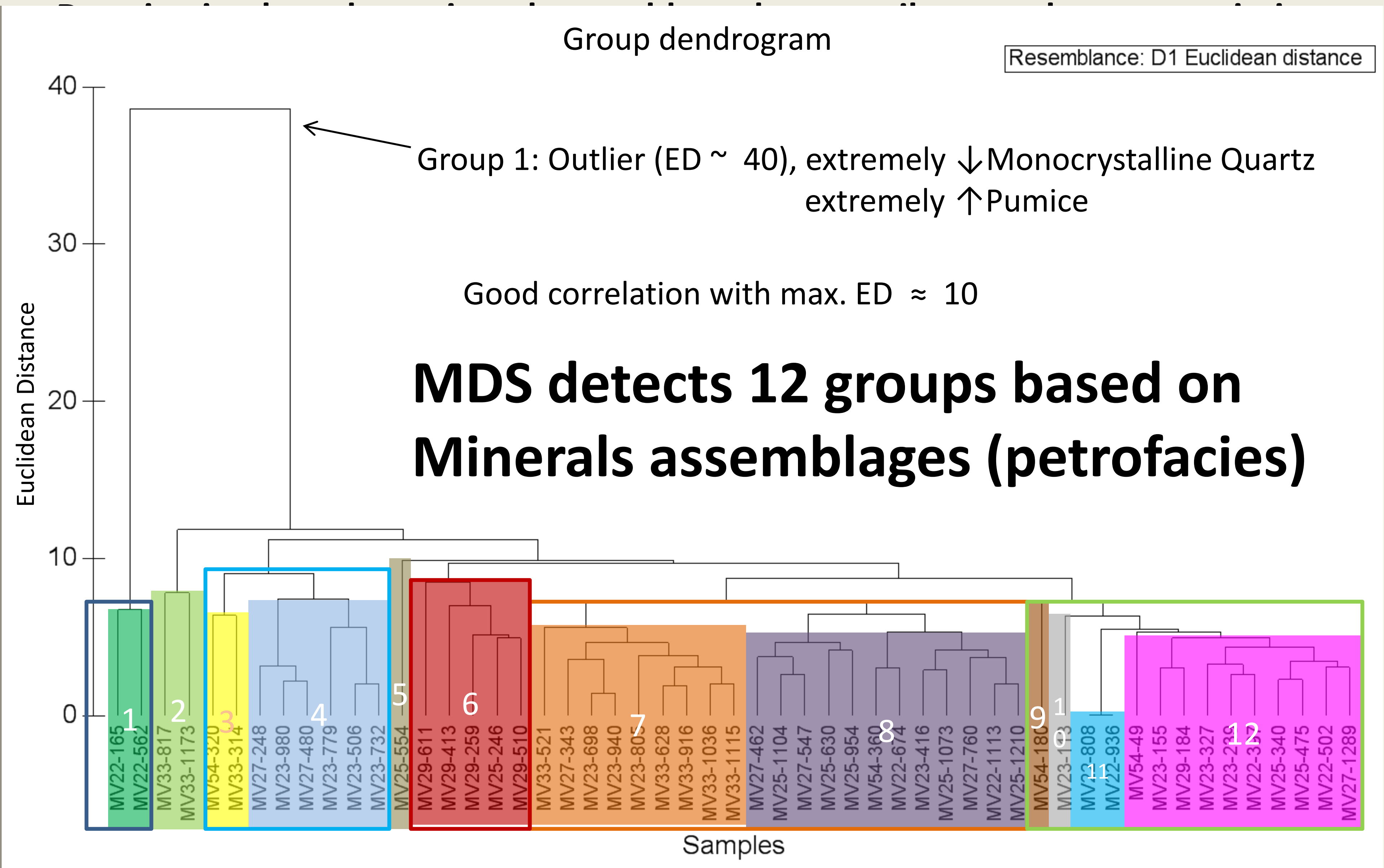
- Prolonged transport in Pandora than Moresby
- More terrestrial erosion signal observed in Moresby
- Volcanogenic input during 22- 17 Ka Bp
- Metamorphic input is significant in Moresby Trough

- ✓ Provenance characteristics
- ✓ Mineral hydraulic behavior
- ✓ Terrestrial Erosion and timing

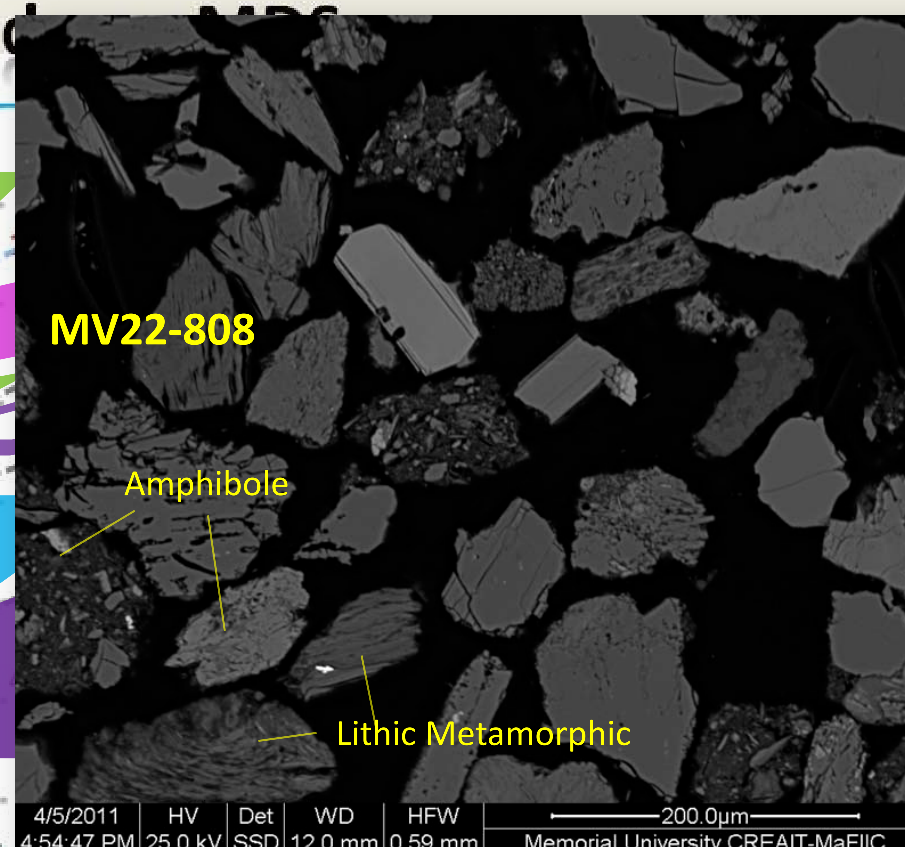
End member (basin) minerals grouping ?

Environmental trends ?

Multivariate analysis 1 → Multi Dimensional scaling



Petro-Facies Based



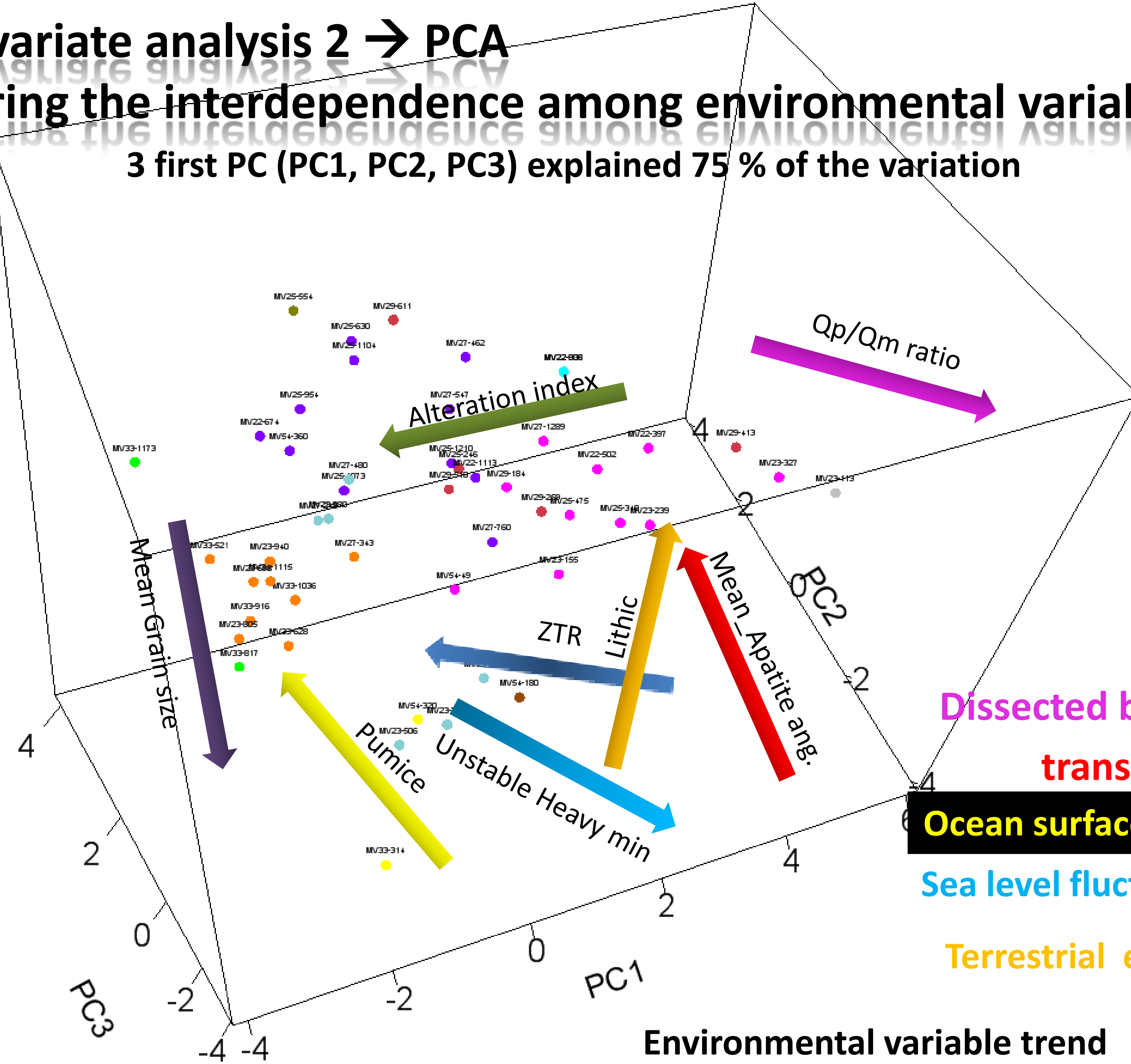
Mixed between system > 15 Ka

- Volcanogenic sand (>30 % pumice)
- Amphibole, Anorthite, pumice
- Perthite, Polycrystalline Quartz
- Quartz, Orthoclase, lithic volcanic
- Lithic volcanic
- Albite, metamorphic fragment, Amphibole

Multivariate analysis 2 → PCA

Exploring the interdependence among environmental variables

3 first PC (PC1, PC2, PC3) explained 75 % of the variation



Dissected basement transport

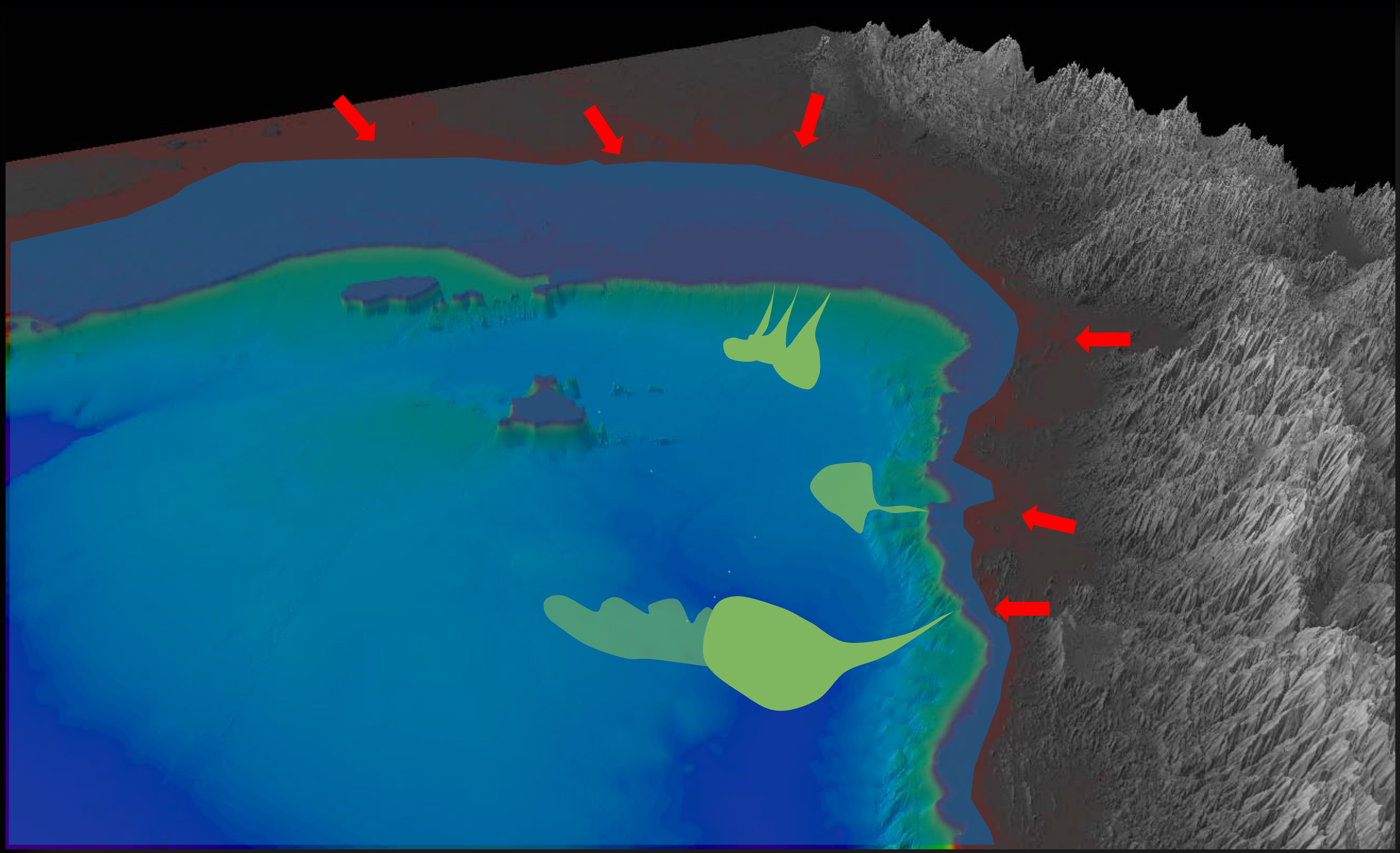
Ocean surface current

Sea level fluctuation

Terrestrial erosion

Environmental variable trend

Background | Physiographic Components | Modal Mineralogy | Multivariate Analysis | **Reconstruction** | Conclusion

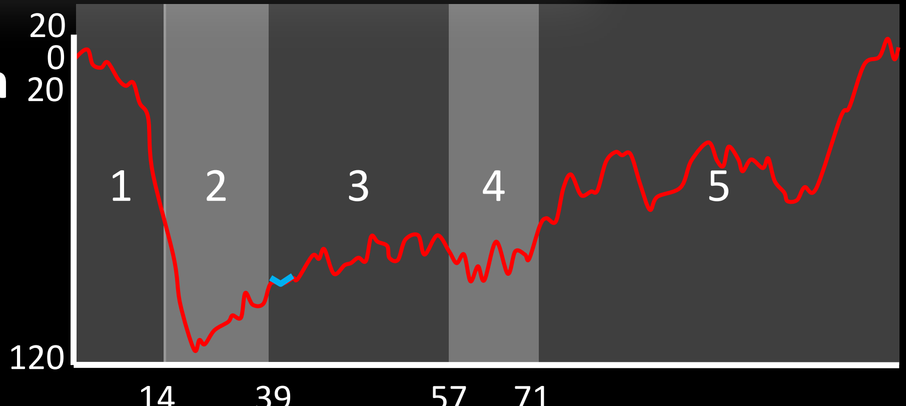


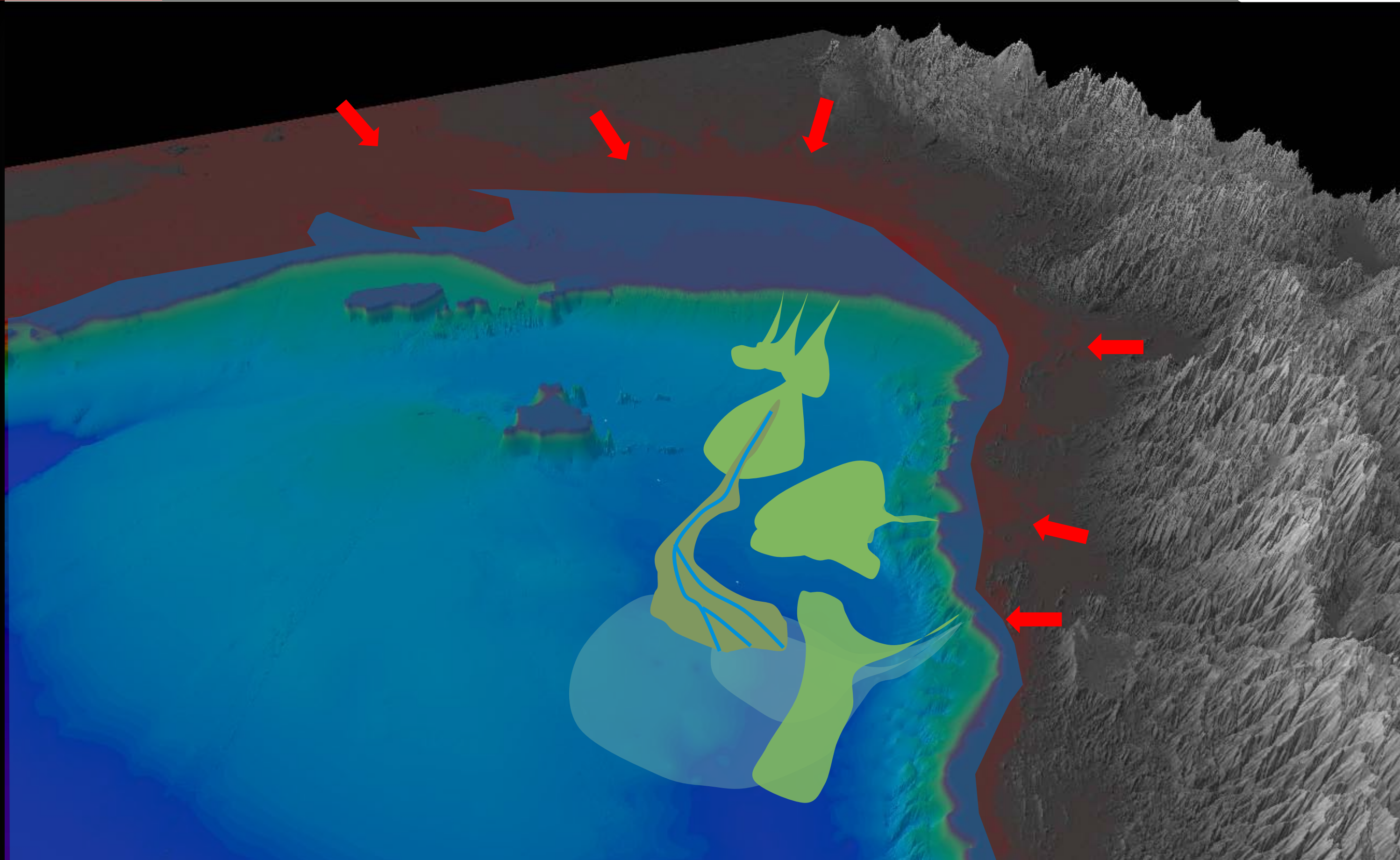
S2S
Reconstruction

1st Stage
(43-40 Ka)

Sea level
50 - 70 mbpsl

- **Low flux of fresh rock to Pandora Trough**
- **Higher supply from Papuan Peninsula which deliver turbidite until EFP**

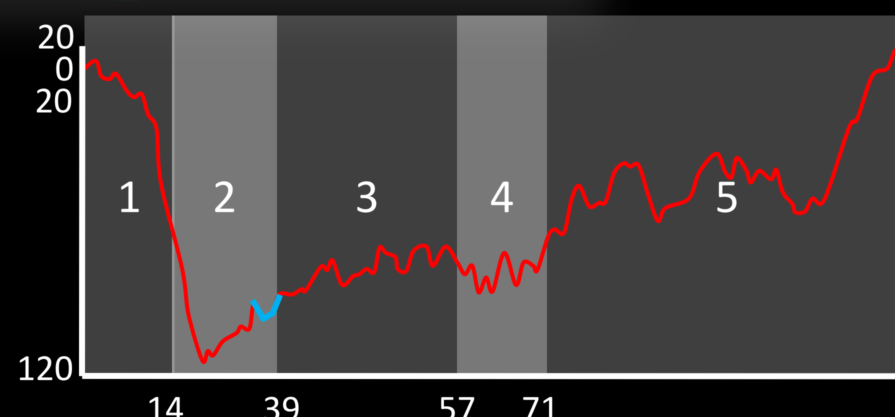


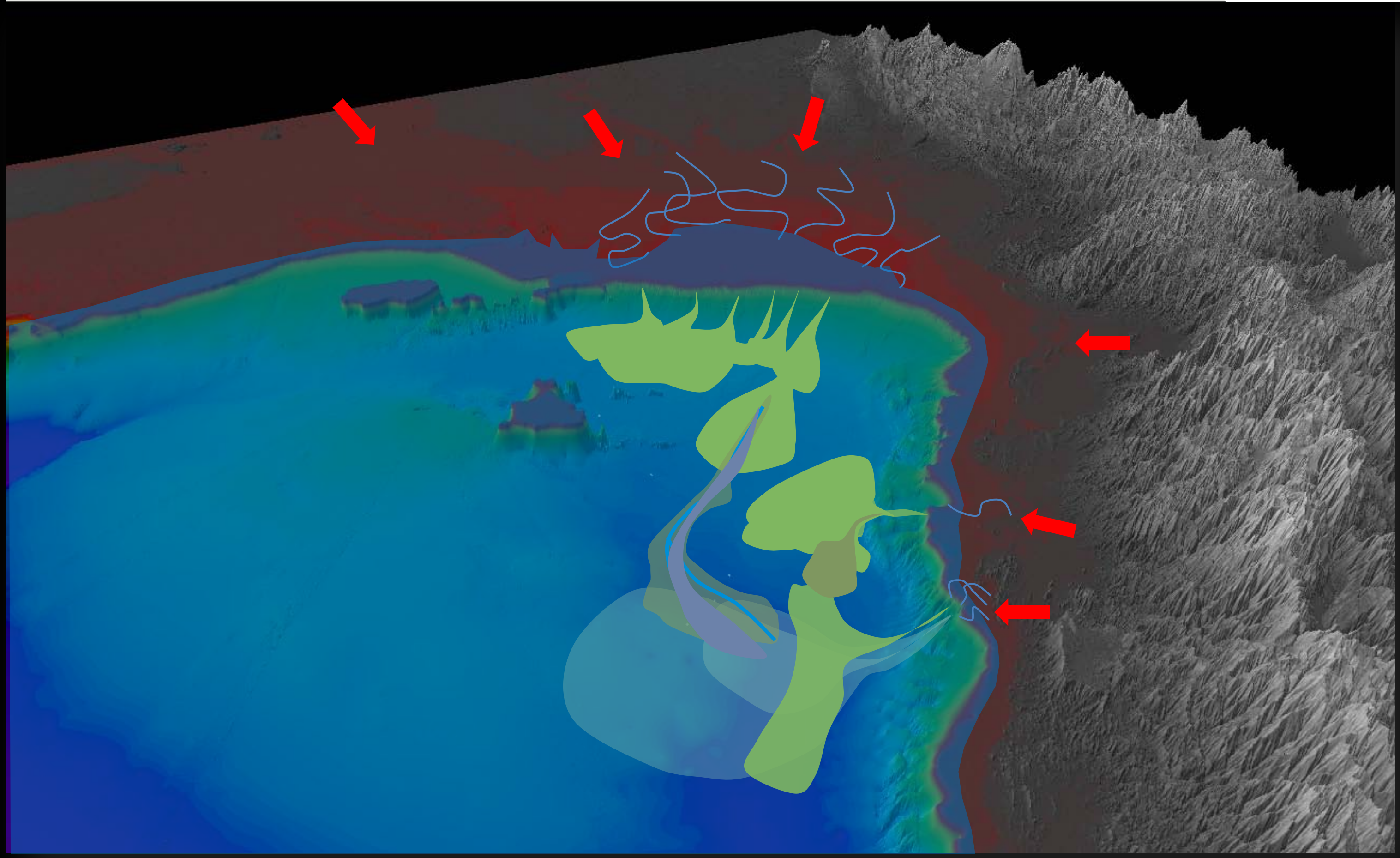


2nd Stage
(39-33 Ka)

Sea level
60 - 80 mbpsl

- **High supply into PT due to rejuvenation on Papuan Mainland**
- **Sediment delivery into EFP switch their direction to PT -EFP**

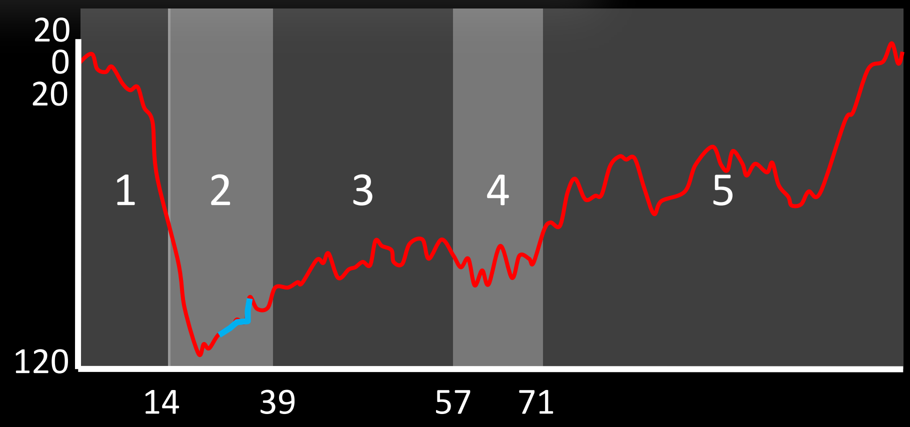


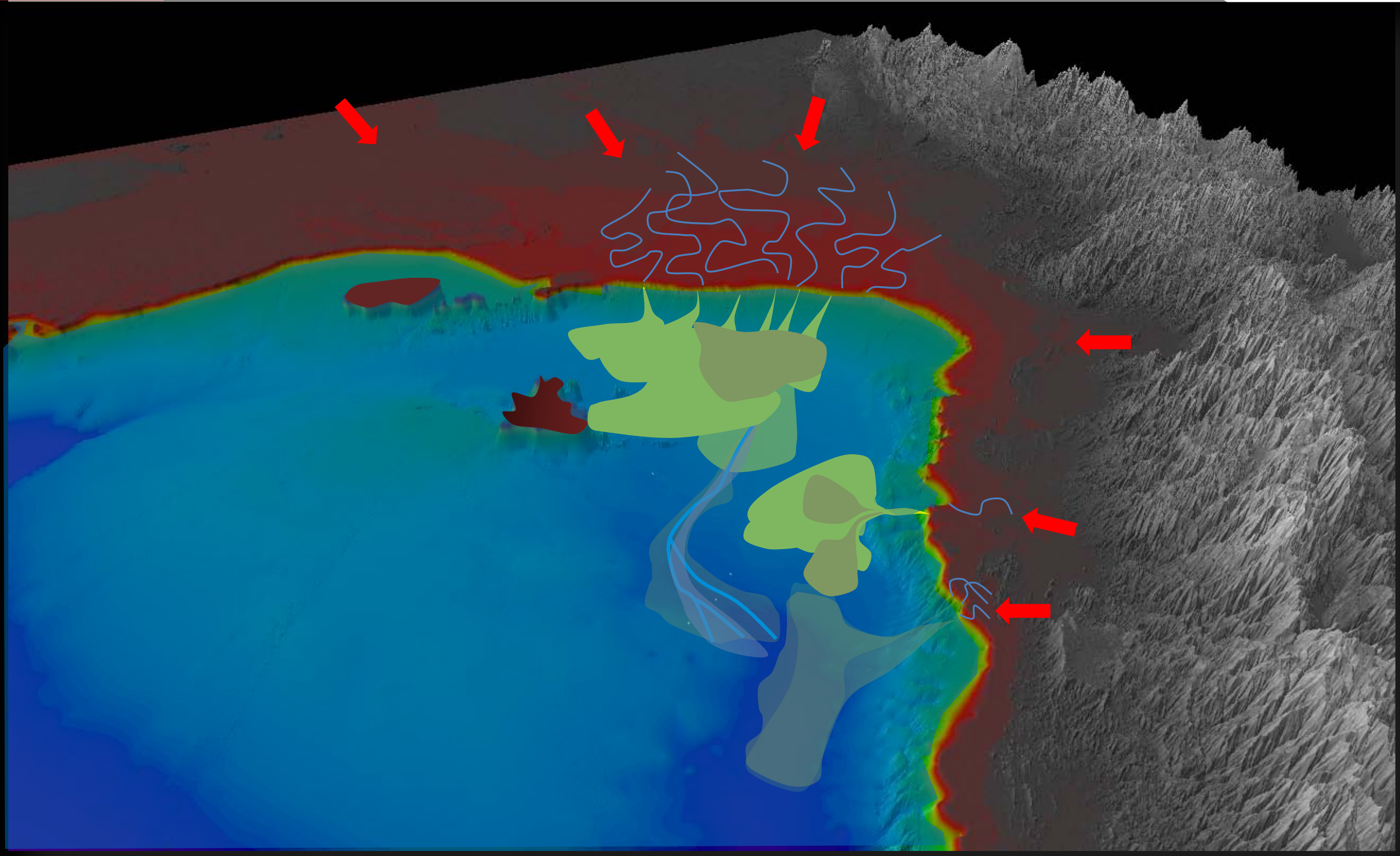


3rd Stage
(26-21 Ka)

Sea level
70 - 90 mbpsl

Deposition on flanks of Eastern Plateau Still continued



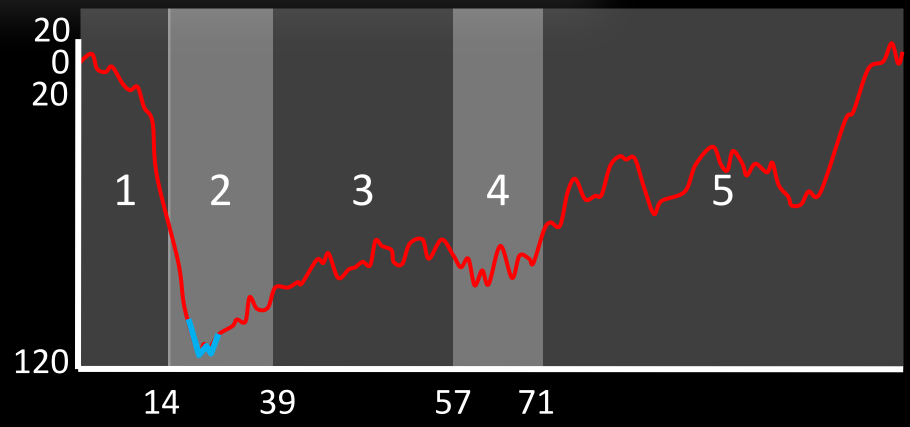


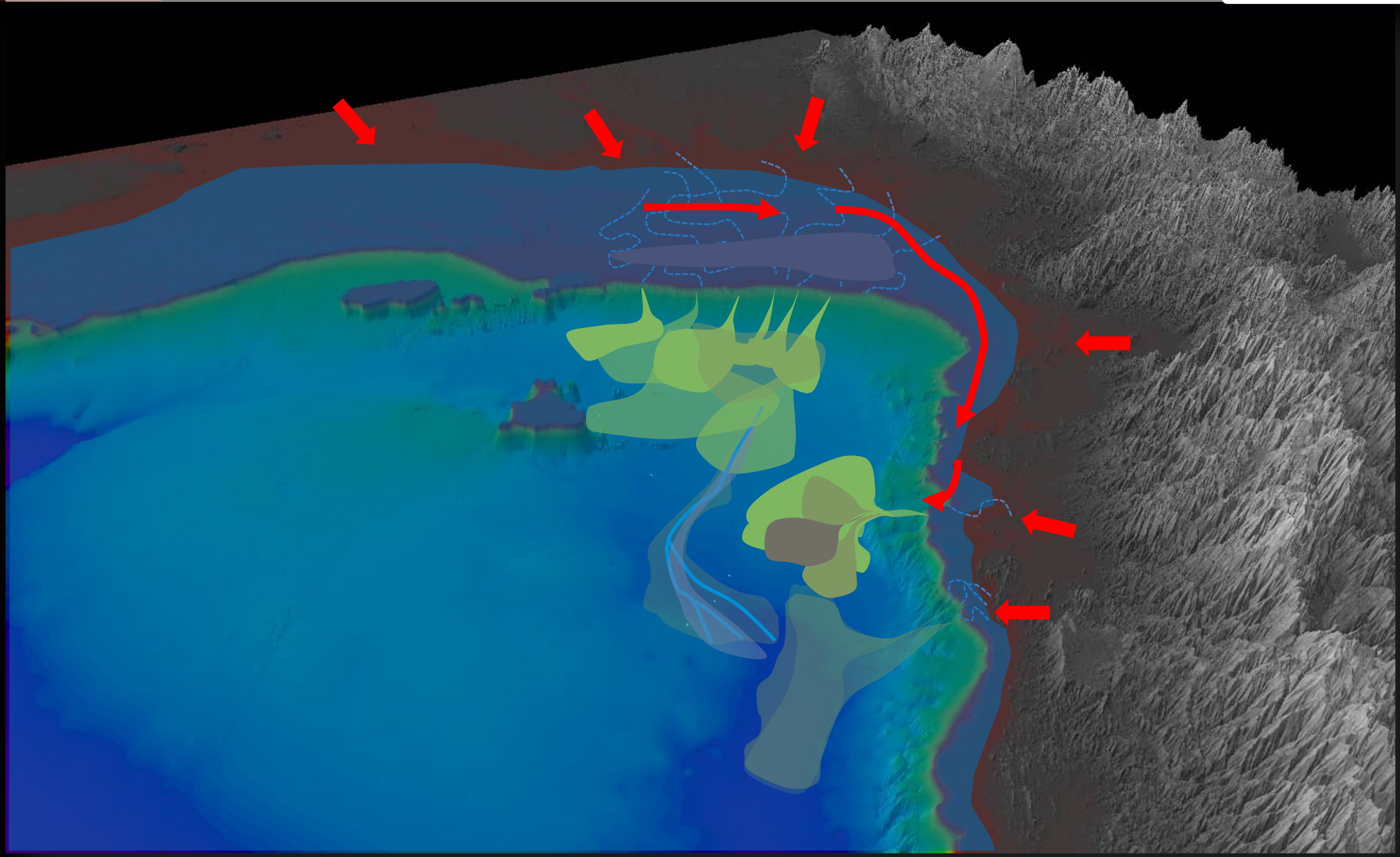
4th Stage
(20-17 Ka)

Sea level

100 – 120 mbpsl

- **peak depositional periods in both troughs.**
- **In Pandora Trough, sediment trapped in mini-basin prevents the deposition to advance further seaward to deep sea**

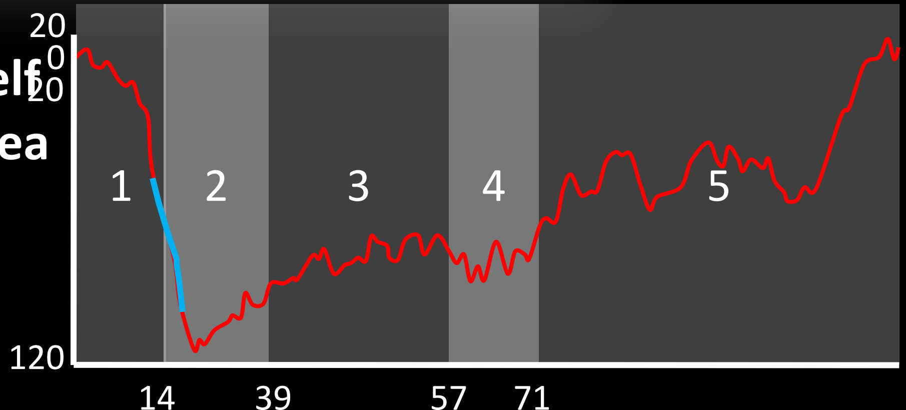


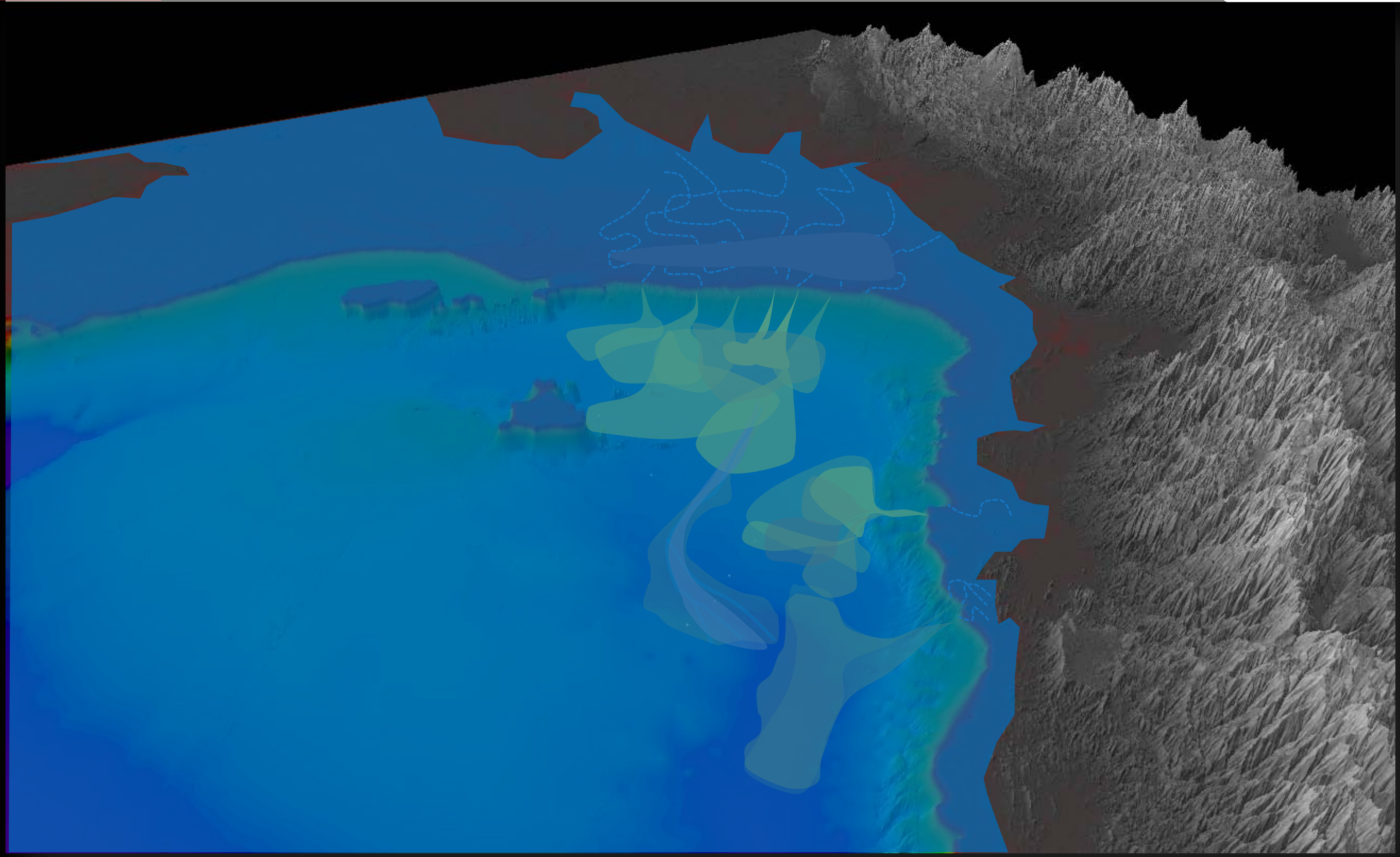


5th Stage
(17 - 11 Ka)

Sea level
40 – 60 mbpsl

•**Sea level high, clinoform formed on the shelf**
Prevent sediment from PT to transfer deepsea
•**Longshore current enables deposition**
into deepwater in Moresby Trough



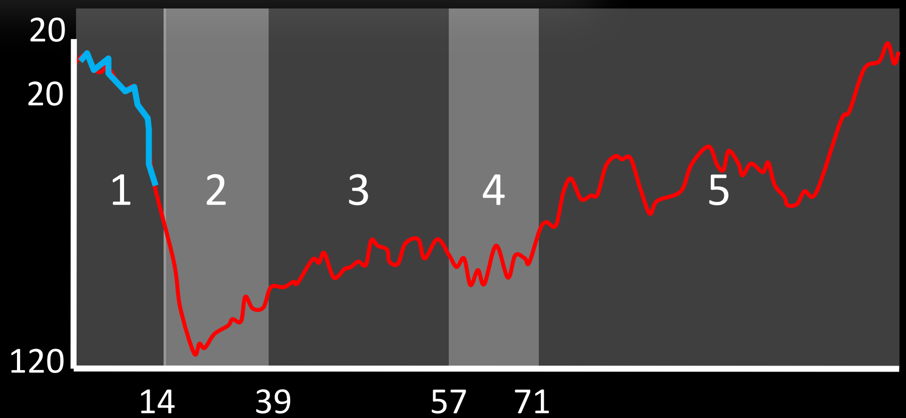


6th Stage

11 - present

Sea level

0 – 40 mbpsl



- **Deposition ceased in both troughs**

CONCLUSIONS

- SEM-MLA analysis is a powerful tool enabling us to differentiate provenance signals and their interdependent variables.
- Variations in mineralogy are mostly contributed from: parental rock inheritance, relative distance to the source and un-roofing rate.
- The **depositional style in** GoP is strongly controlled by:

Shelf width – **vicinity to sources** – **sediment flux** and **ocean processes**

- **Important implication to geoscience** :

  Deepwater depositional processes could develop in **any sea level condition**, although sea level fall still is needed to accelerate the processes.

Acknowledgement

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- Schlumberger Petrel

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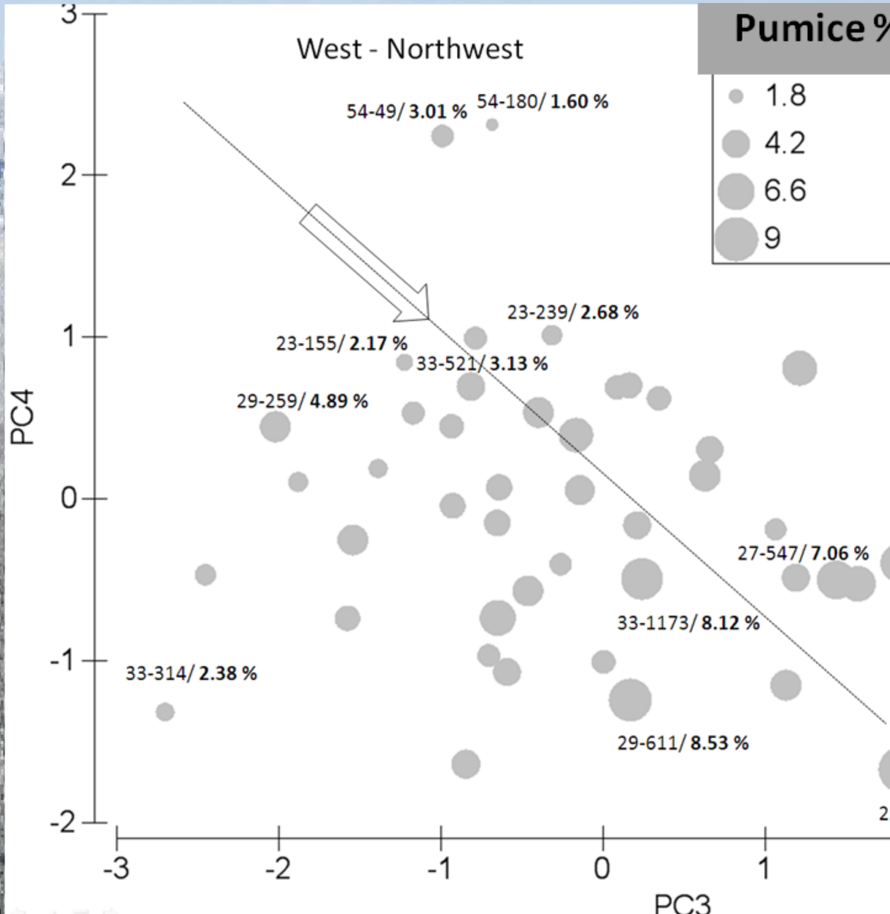
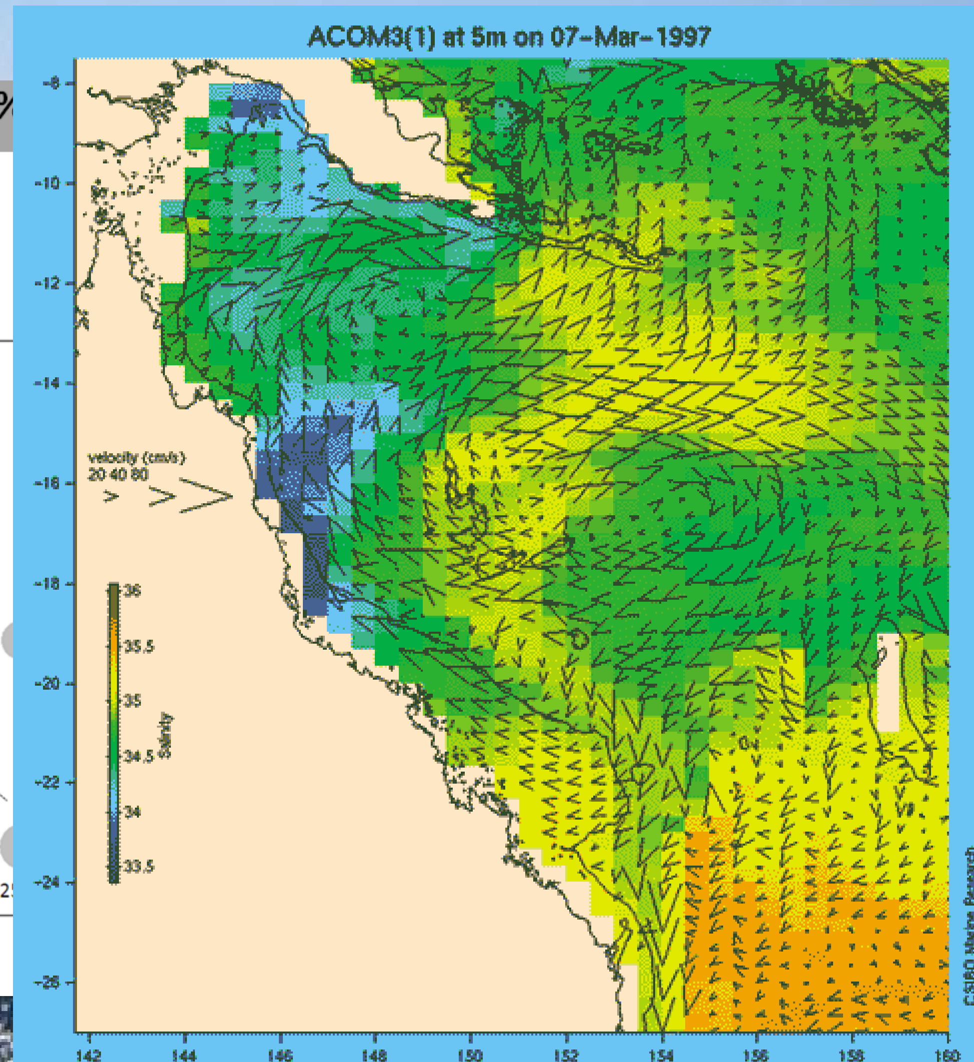
Pumice Trend





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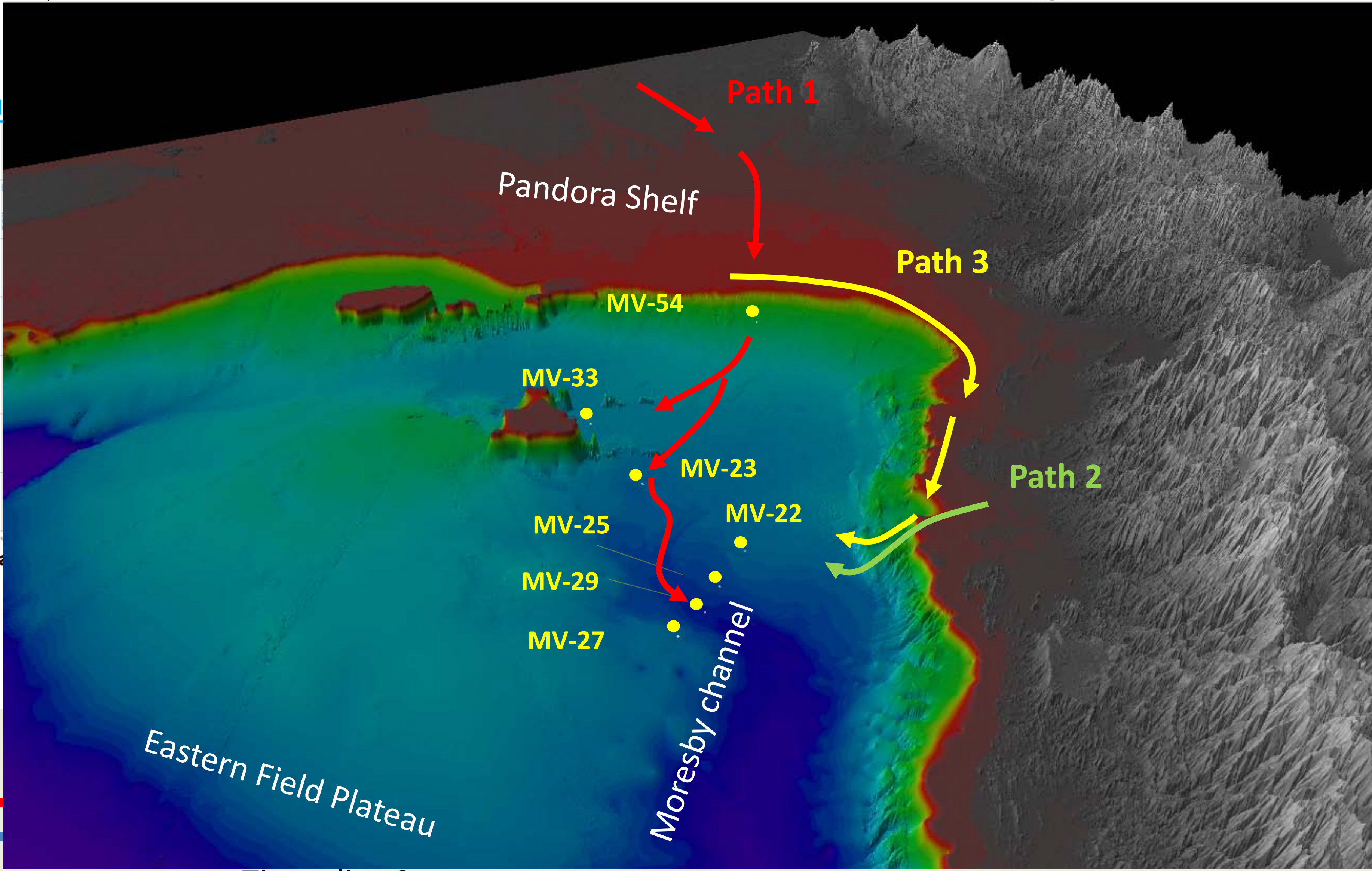


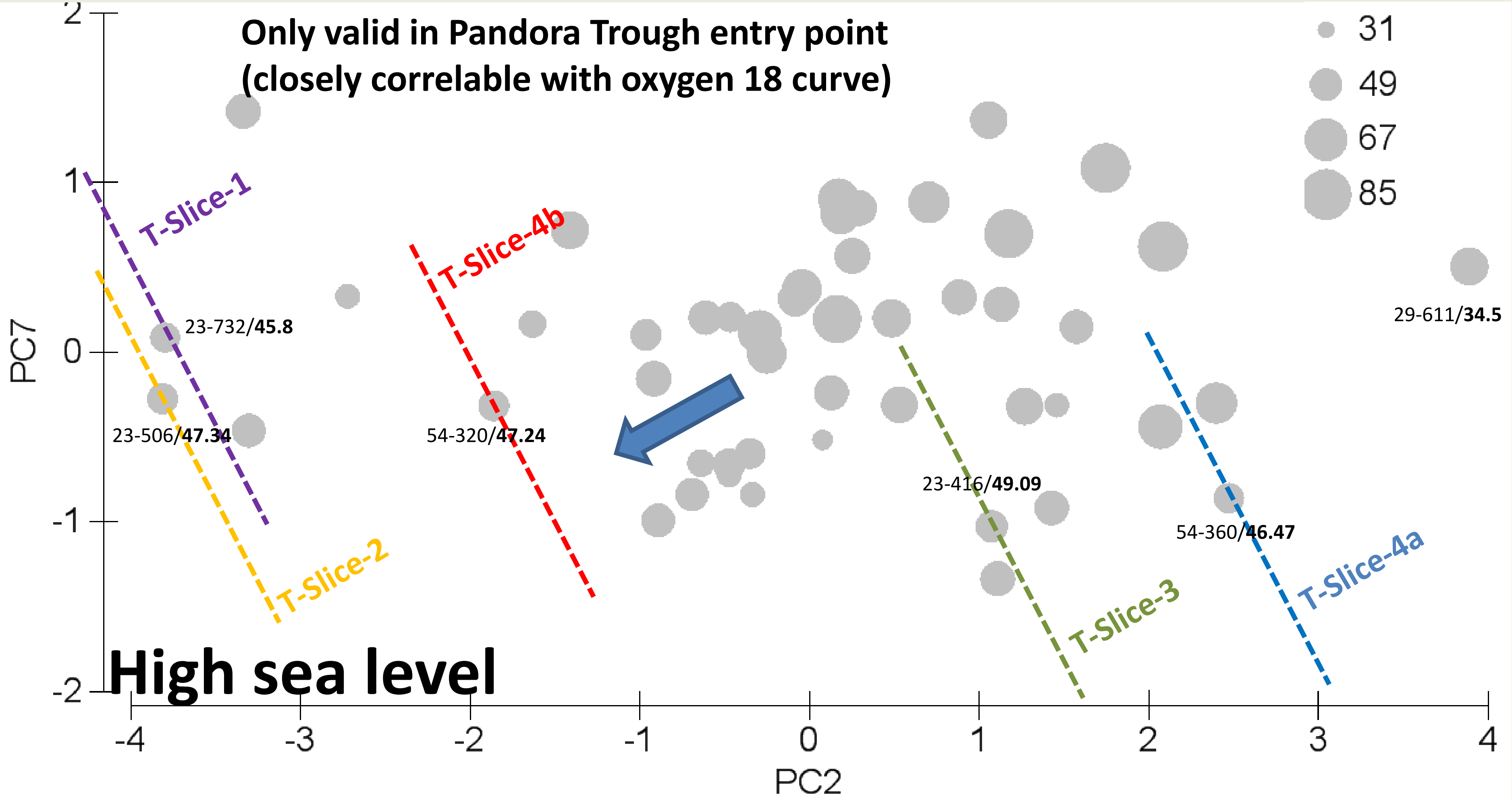
Time slice 3
Time slice 2
Time slice 1 (42 Ka)

∫ Apatite Angularity * QP/Qm index

Function of:

-Distance from source to intermediate sink (entry point)

-Sea Level fluctuation



Apatite grains become rounder with longer-distance transport .

Monocrystalline quartz is preferentially preserved over long-distance transport.