Thesis research plan: Magnetostratigraphy and rock magnetism in the western US

Constraints on the age, sedimentation rate, source, and hydrodynamic setting of Cenozoic continental sediments related to the CR-Yellowstone plume system

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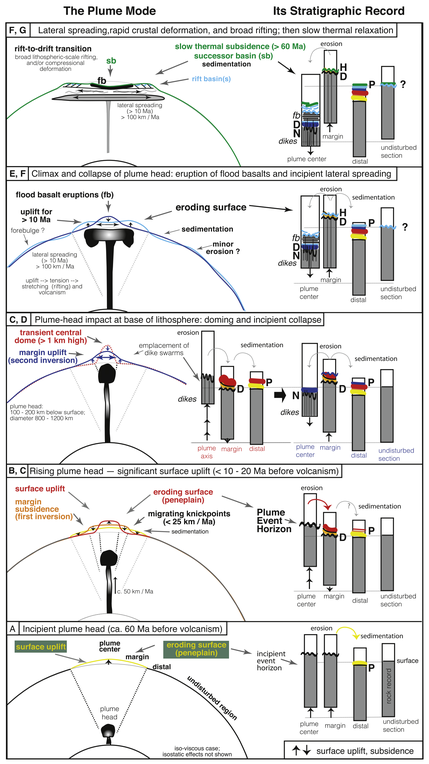
The concept of the UPLIFT project



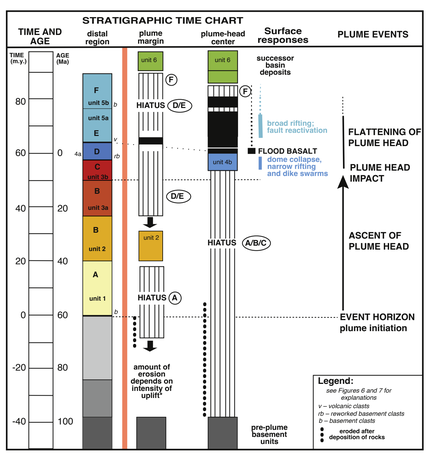


Figure 1. The plume model predicts how deposition centers will vary in time and space (**top**).[4] Detailed chronostratigraphic charts show how the uplift signal is recorded in different locations with respect to the plume head (**bottom**).[4] Border between the marginal and distal region (**orange**) is also shown in Figure 2.

Abstract

The UPLIFT project aims to better understand and separate the processes of classic plate tectonic theory from **vertical motion driven by mantle plumes**. The so-called "unifying Plume-Mode-Stratigraphic Model" arising from dynamic topography envisages a change in time and place where sediments should be deposited as the height and width of the plume slowly increases and then abates (Figure 1). As continentally-derived sediments are notoriously fossil poor, they are hard to date with classic paleontology, making magnetostratigraphy a desirable tool to constrain their ages.

Magnetostratigraphy provides a continuous, high-resolution time record of the sediments whose detailed sedimentation rates can be used to reconstruct the exhumation and erosion histories (Figures 3-6). Moreover, by studying variations in magnetic mineralogy and sedimentary fabric through time, one can trace potential changes in source rock and/or the hydrodynamic regime acting during sedimentation. The magnetism research group in Munich has carried out several such studies in Central Asia.[1-3] The same methodology will be applied to **basins related to the Columbia River-Yellowstone plume system in the western US** (Figure 2) and the first field study has just been carried out.

Study objectives

Determining the age, sedimentation rate, source, and hydrodynamic setting of Cenozoic sedimentary sections in the northwestern US from magnetic studies

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Placing constraints on the changing dynamic settings related to the ascending and dispersing CR-Yellowstone plume system

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Input data for geodynamical modelling of mantle plumes

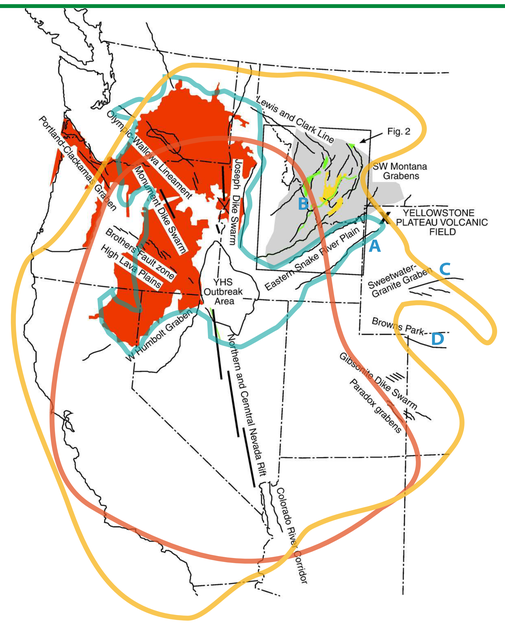


Figure 2. Map showing narrow grabens and radial dikes (**black**) and flood basalts (**red**) of Middle Miocene age in the western United States that are radial to the outbreak area of the Yellowstone hotspot (YHS).[5] Outlines show the postulated positions of the plume head at 46 Ma (**yellow**), 32 Ma (**orange**), and 17 Ma (**green**), after the model shown in Figure 1.[4] Labeled A - D (**blue**) are the selected locations for a magnetostratigraphic and rock magnetic study, of which the first sampling compaign just completed.

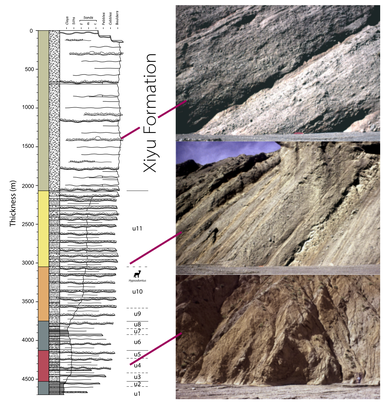


Figure 3. The Tianshan domain in central Asia serves an excellent example of difficulties experienced in dating when no magnetic data is available, as it contains very similar-looking sequences of coarsening-upward continental sediments that are fossil poor (**right**). The coarse conglomerates at the top of the sections were mapped as a single formation, called the Xiyu Formation (**left**).[1] The Xiyu conglomerates were interpreted to be the same age, created by a regional change in climate.[6] This idea turned out to be false - a similar tectonic style produces similar sedimentation packages regardless of time.[2] Such similar looking sequences can easily differ by over 20 Myr.

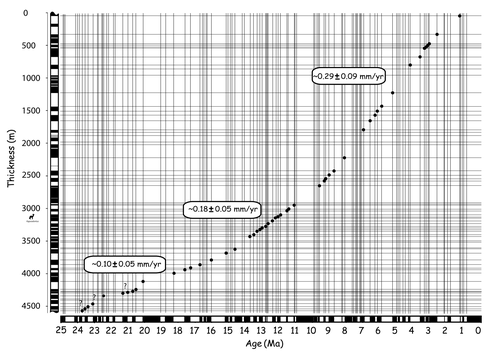


Figure 4. Once the age model is assigned, sedimentation rates and their evolution over time can be studied. In this example, sedimentation rate tripled from 24 to 1 Ma (**left**).[1] Moreover, magnetic susceptibility, which serves as a proxy for magnetite concentration, increased with time (**right**).[1] Punctual changes in magnetic susceptibility appear to coincide with abrupt changes in sedimentation rate (**middle**), which were interpreted as heightened erosion of a source rock that was more enriched in magnetite.[1]

Methodology - applied to Central Asia

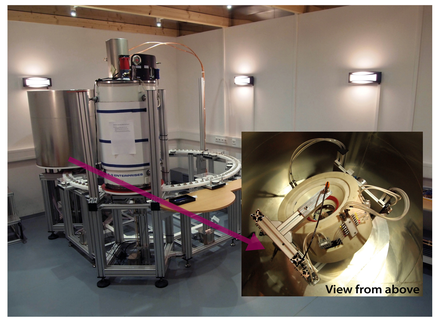


Figure 5. All analyses will be conducted in the LMU paleomagnetic laboratory using the "SushiBar" - a fully automated system that can conduct stepwise alternating field demagnetization and measure 99 samples simultaneously.[7]

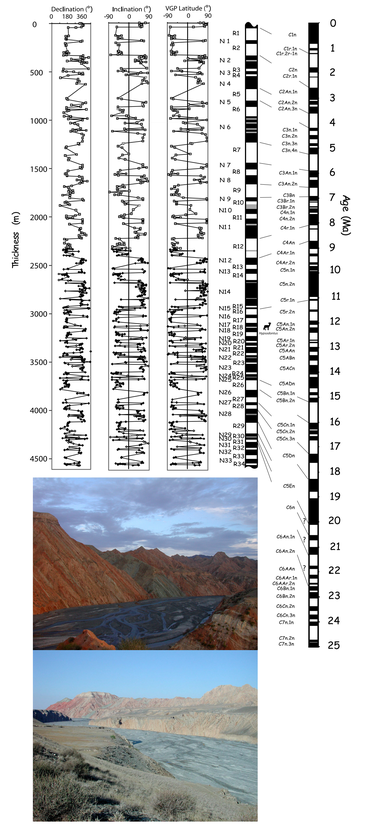
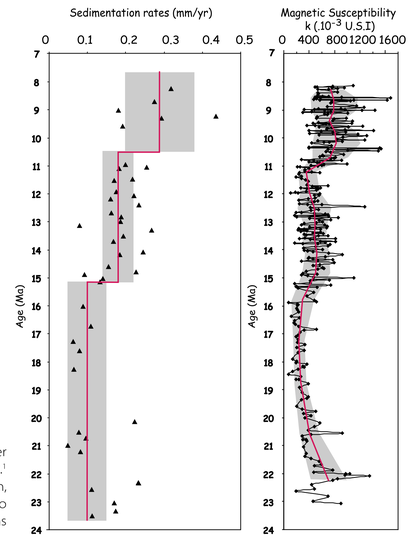


Figure 6. The Jingou River section (**bottom**) serves a good example of an integrated rock and paleomagnetic study.[1] After collecting and demagnetizing >1000 samples, a magnetostratigraphic column was constructed (**top left**) that could be compared against a global reference model (**top right**) to establish absolute ages as a function of depth.



References

[1] Charreau, J., et al. (2009a). Neogene uplift of the Tian Shan Mountains observed in the magnetic record of the Jingou River section (northwest China), *Tectonics*, *28*, TC2008.

[2] Charreau, J., et al. (2009b). The Neogene Xiyu Formation, a diachronous prograding gravel wedge at front of the Tianshan: Climatic and tectonic implications, *Earth and Planetary Science Letters*, *287*, 298–310.

[3] Macaulay, E., et al. (2016). The sedimentary record of the Issyk Kul basin, Kyrgyzstan: Climatic and tectonic inferences, *Basin Research*, *28*(1), 1–24.

[4] Friedrich, A.M., et al. (2018). Stratigraphic framework for the plume mode of mantle convection and the analysis of interregional unconformities on geological maps. *Gondwana Research*, *53*, 159-188.

[5] Sears, J.W., et al. (2009). Stratigraphic record of the Yellowstone hotspot track, Neogene Sixmile Creek Formation grabens, southwest Montana. *Journal of Volcanology and Geothermal Research*, *188*(1-3), 250-259.

[6] Zhang, P, et al. (2001). Increased sedimentation rates and grain sizes 2–4 Myr ago due to the influence of climate change on erosion rates, *Nature*, *410*, 891-897.

[7] Wack, M. & Gilder, S. (2012). The SushiBar: An automated system for paleomagnetic investigations, *Geochemistry, Geophysics, Geosystems*, *Q12Z38*.

Funded by

Deutsche Forschungsgemeinschaft

German Research Foundation

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