Do grain size patterns from Oligo-Miocene Swiss Molasse sequences reflect shifts in sediment flux through time?

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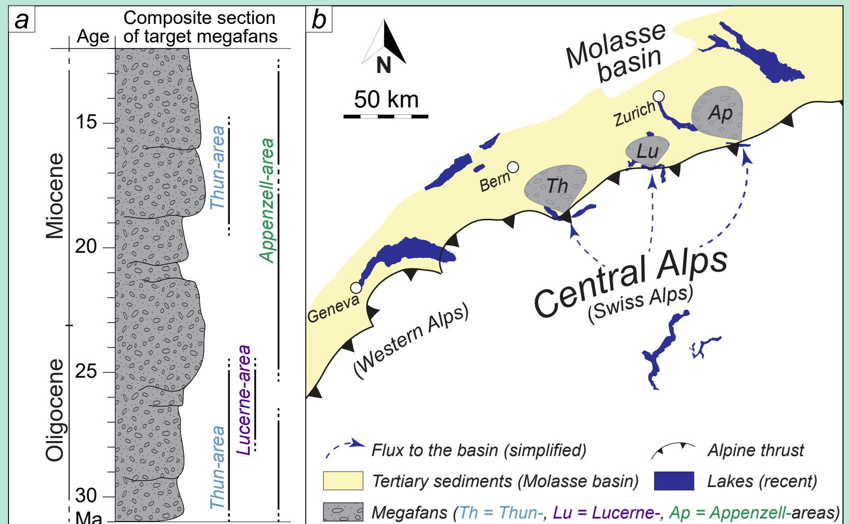
Motivation & Study Area

Grain size trends preserved in large-scale coarsening- and thickening-upward sequences within foreland basins reflect the evolution of the adjacent mountain belt. The stratal pattern is controlled to a high degree by tectonic, lithologic or climatic controls and which lead to variations in hydrological conditions, and which also control sediment discharge. In this study, we investigate whether there exists a direct relationship between grain size and discharge rates (or sediment flux), as proposed by pioneer studies in fluvial hydraulics (e.g. Lane, 1955).

We focus on km-thick conglomerate sequences of the Swiss Molasse basin (Fig. 1a) including three major depositional systems, our target megafans, situated in eastern, central, and western Switzerland (Fig. 1b). We compare grain size data, measured with state-of-the-art measuring techniques, to published patterns on sediment flux (Kuhlemann et al., 2001), that have been calculated for catchments of the Swiss (Central) and Western Alps that drained towards the North and West only.



1a: Stratigraphy
General stratigraphy of the study area encompassing the three depositional systems (target megafans) with their relative time range. Individual sections have been dated through magneto-polarity chronolgies (Schlunegger et al., 1997; Kempf et al., 1999).

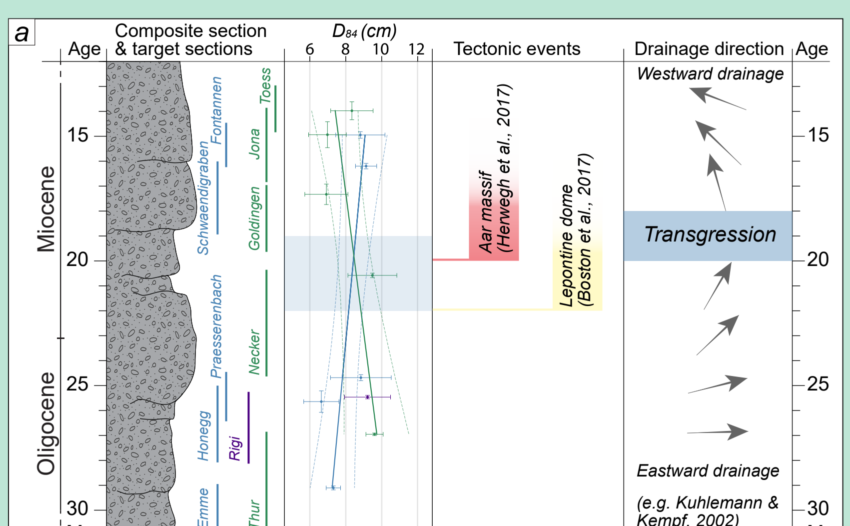
1b: Study area
Molasse basin with target megafans at their approximate location in relation to the Alps. Lakes and city names for orientation.

Interpretation & Discussion

At the section scale (Figs. 2b & c): Individual sections show an increase of the D_{84} and D_{50} through time, reflecting coarsening trends up-section due to the progradation of the megafans and the downstream grain size fining from proximal to distal positions (spatial effect).

At the megafan and basin scale (Figs. 2d & e): The D_{84} and D_{50} of entire sections (Fig. 2d) and of proximal parts only (Fig. 2e) display a shift from east to west at c. 22-19 Ma (i.e. prior this period, D_{84} and D_{50} are larger in the east, and vice versa after this period).
This change occured simultanously with major tectonic events in the Central Alps (Fig. 1a & 4a) leading to perturbations of the catchments and their stream network. Furthermore, the shift occurred around the time when drainage directions of the target megafans changed from an eastward to a westward oriented discharge (Fig. 4a).

It appears that the overall trend in sediment flux through time is not primarily reflected by shifts in grain size at the basin scale, but these shifts might reflect the individual catchment evolution and sediment routing of the observed target megafans.

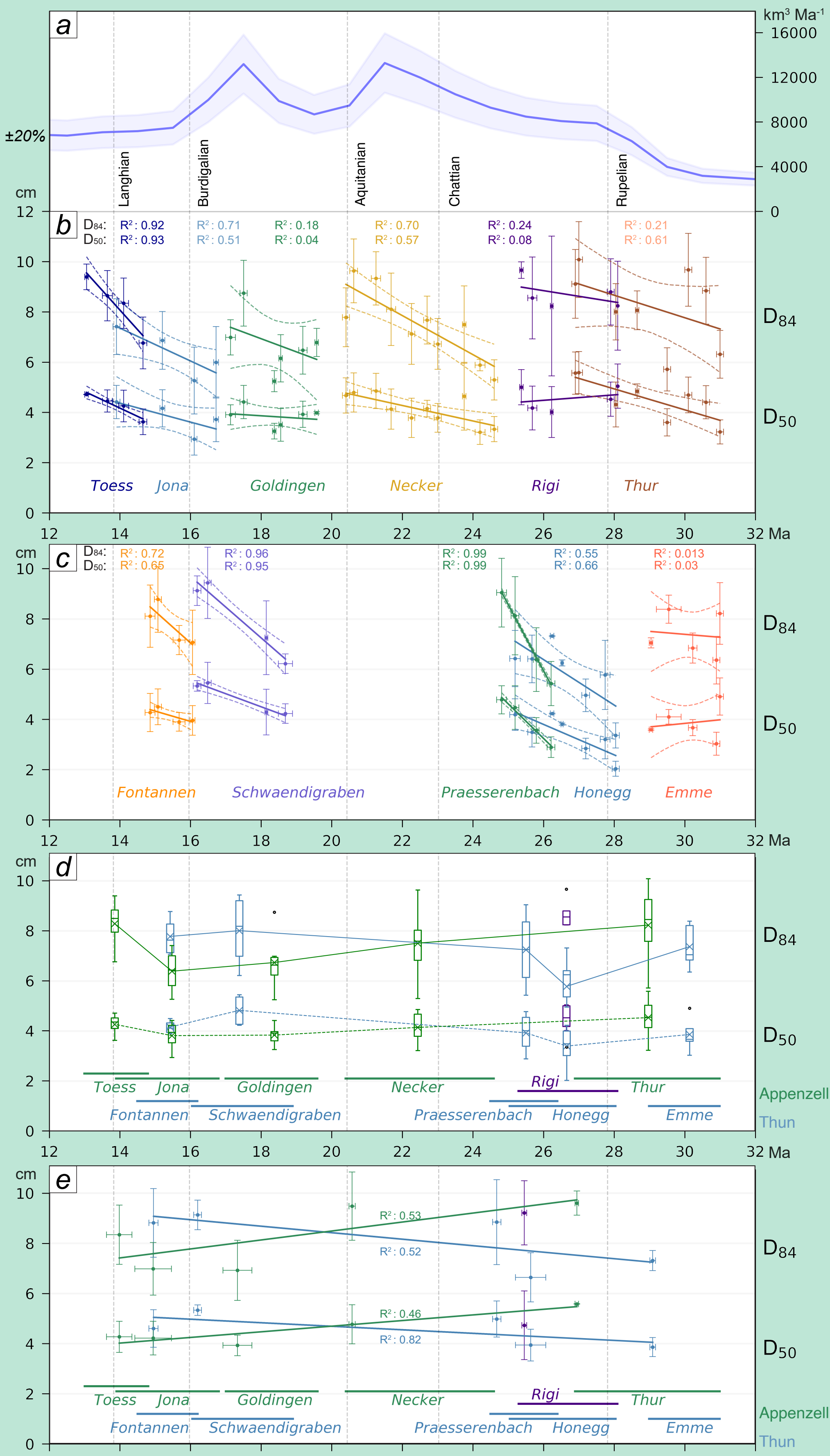


4a: Key observations
The shift in grain size (west becomes coarser than east, see also Fig. 2e) occured between c. 22-19 Ma, during a time when:

i) the Aar massif was exhumed & a rapid tectonic exhumation of the Lepontine dome occurred,
ii) the drainage direction for all areas changed from east to west, and
iii) a basin wide transgression took place.

Interestingly, a remarkable drop in sediment flux occured at the same time (Fig. 2a), following Lane (1955), we would expect grain size to become finer. However, this effect might have been buffered by adjustments in the catchments and by exposure of new lithologies.

Results



2a: Sediment flux
After Kuhlemann et al., 2001; Sediment discharge rates of catchments of the Swiss (Central) and Western Alps that drained to the North and West only. Calculations are based on thickness maps, restored sections and drillcores.

2b & 2c: Grain size per 0.5 Ma bins
Data shows the average grain size (D_{84} and D_{50} percentiles) per 0.5 Ma bins with linear regressions of data per section with a 95% confidence interval. The R^2 values indicate Pearson's coefficient of determination. Error bars represent one standard deviation. We observe that several sections having considerable regression coefficients (i.e. > 0.5) show **increasing D_{84} and D_{50} trends** up-section (see also discussion).

2b: Data of Appenzell area (East) and Rigi section (Lucerne area; Central)
The Appenzell area includes 6 individual sections with a total of *144 outcrops*; Toess: 46, Jona: 13, Goldingen: 23, Necker: 52, and Thur: 10 outcrops. The Rigi section counts 28 outcrops.

2c: Data of Thun area (West)
The Thun area consists of 5 individual sections with a total of *158 outcrops*; Fontannen: 50, Schwaendigraben: 10, Praesserenbach: 64, Honegg: 24, and Emme: 10 outcrops.

2d: Average grain size in sections
Boxplots of D_{84} and D_{50} (0.5 Ma bin-data) for the Appenzell (green) and Thun (light blue) areas, and for the Rigi section (dark blue).

Straight lines connect overall averages (marked with x) of the Appenzell and Thun areas (circles = outliers of D_{84} (Rigi, Goldingen) and D_{50} (Rigi, Emme). The Horizontal bars show the age range of the corresponding sections.

2e: Proximal positions on megafans
Average D_{84} and D_{50} values for the proximal part of each section only. This includes the topmost 300 m of each section, which have been deposited at proximal positions on the megafan as facies analysis revealed.

The linear regressions show a pronounced decreasing trend for the Appenzell area, and a clear increasing trend through time for the Thun area (for both percentiles, D_{84} and D_{50}).

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