Magma source variations of late Cretaceous-late Eocene magmatic rocks of the Chilean Precordillera (21.5°-26°S): Due to variable water fugacity or crustal thickening ?

SFB 267
Deformation Processes
in the Andes

Michael Haschke[1], **Andreas Günther**[1], **Wolfgang Siebel**[2], **Ekkehard Scheuber**[1], **Klaus-Joachim Reutter**[1]

[1]SFB 267, Institut für Geologie, Geophysik und Geoinformatik, Freie Universität Berlin, 12249 Berlin, mrh@zedat.fu-berlin.de

[2]Geoforschungszentrum Potsdam, Telegrafenberg B123, 14473 Potsdam

Introduction

Our study attempts to apply REE patterns of late Cretaceous-late Eocene arc magmatism in the Chilean Precordillera as a guide to crustal thickness through time (Fig.1). Modern studies on Miocene to recent Andean arc magmatism (Hildreth & Moorbath 1988, Kay et al.1987, 1991, 1994) apply an increasing slope in REE patterns through time (indicated by increasing La/Yb and La/Sm ratios through time) as a guide to increasing crustal thickness through time.

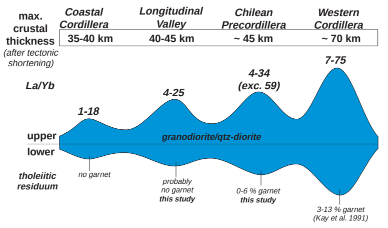
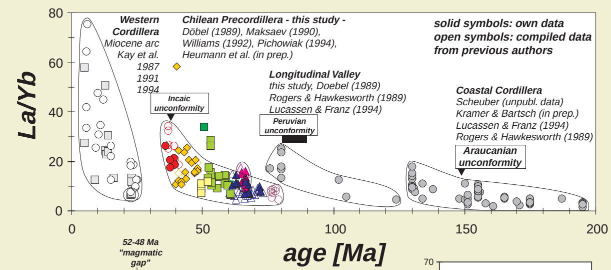


Fig. 1: Schematic mechanism of La/Yb correlation with crustal thickness of Andean arc systems (0-200 Ma), as proposed by Kay et al. 1987, 1991, 1994 and Hildreth & Moorbath 1988.



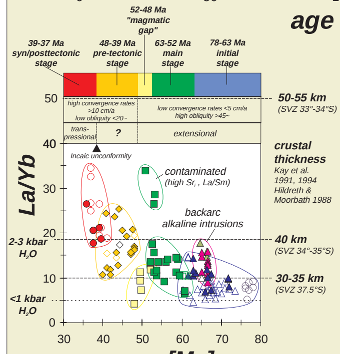


Fig. 2 and 3: La/Yb vs Andean age (0-200 Ma) and vs age of the Chilean Precordillera (78-37 Ma). Andean magmatism displays repeated La/Yb cycles in each magmatic arc system. Note increasing maximum La/Yb ratios through Andean system after tectonic shortening & crustal thickening. La/Yb ratio increases through time occur at equal SiO_2 ranges. Tepper et al. (1993) proposes increasing pH_2O (<1 to 2-3 kbar) as a possible mechanism to raise La/Yb ratios through time. La/Yb is highest after tectonic shortening, but also increases throughout the time of arc magmatism.

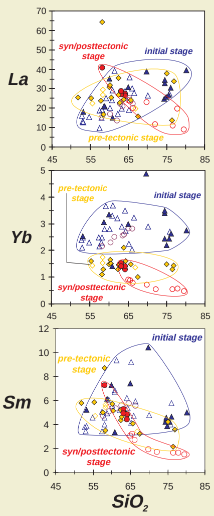


Fig. 4: La, Yb and Sm vs SiO_2 Chilean Precordillera
La, Yb and Sm-contents change through time. Variable La behaviour through time is due to different fractionation paths through time. Variable Sm and Yb-behaviour is controlled by increasing hbl and gt-content in the residuum mineralogy through time.

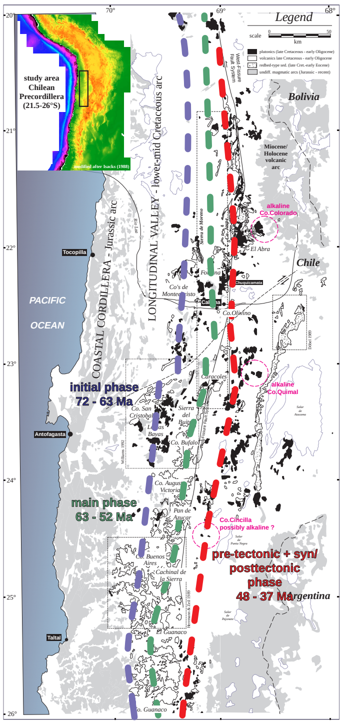


Fig. 5: Schematic tectonomagmatic overview of the late Cretaceous to late Eocene arc system of the Chilean Precordillera (21.5° - 26°S).

influence of hbl - gt residuum on REE pattern

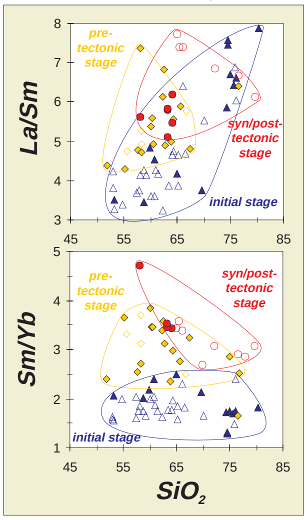


Fig. 6 and 7: La/Sm and Sm/Yb vs SiO_2.
Increasing La/Sm and Sm/Yb through time indicate increasing hbl-retention and particularly garnet-retention in the residuum mineralogy. The different La/Sm and Sm/Yb behaviour through time at equal SiO_2 also suggests different fractionation paths.
Increasing crustal assimilation through time can be excluded as an influencing variable, since La contents in the youngest arc rocks are lower and decrease with increasing SiO_2.

influence of feldspar FC on REE pattern

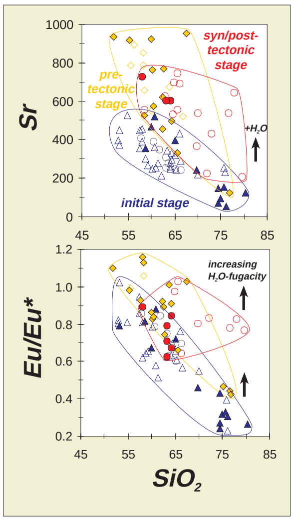


Fig. 8 and 9: Sr and Eu/Eu* vs SiO_2.
Increasing Sr-contents and Eu/Eu* ratios through time at equal SiO_2 suggests decreasing importance of feldspar fractionation through time due to increasing H_2O-fugacity through time.

Sr and Nd isotopic signature

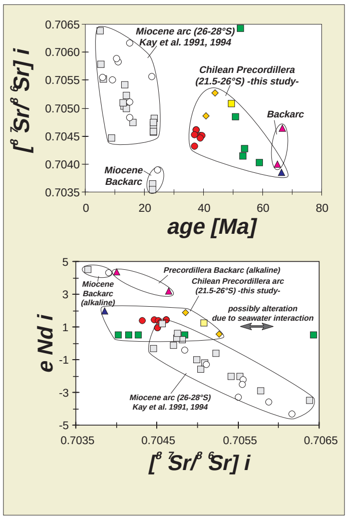


Fig. 10 and 11: Sr_i vs eNd_i and age vs Sr_i.
A weak trend of ncreasing Sr_i through time accompanies the increasing La/Yb ratios through time. Increasing Sr_i at largely constant eNd_i points to contamination of the isotopic system by seawater interaction. Crustal contamination with old crust can be neglected.

LILE, HFSE and REE modelling

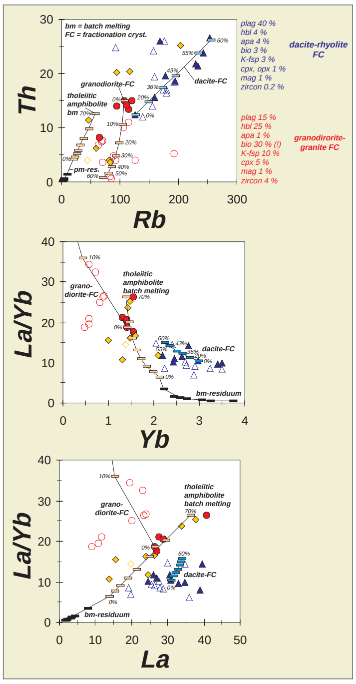
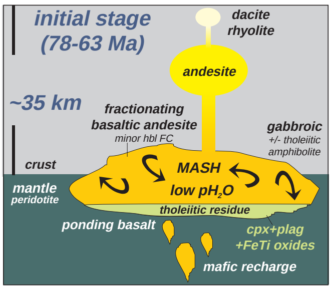


Fig. 12, 13 and 14: Modelling of FC paths through time in the Chilean Precordillera.
Rb vs Th modelling suggests a plag-dominated fractionation +bio + K-fsp +minor zircon to produce the observed dacite to rhyolite evolution in the initial stage (78-63 Ma).
A hbl- and bio-dominated FC mineral assemblage, with only minor plag, can explain the granodiorite to granite evolution. The unreasonable amount of bio-FC, however, remains an unsolved problem.

The modelled FC mineralogies also fit the REE pattern evolution through time. High degrees (50-60 %) of partial melting of tholeiitic amphibolite can produce a REE pattern of the observed dacitic source composition. 10 % FC is able to generate rhyolitic/granitic compositions from these dacites.

Kd's after Martin (1987) and a compilation of Rollinson (1993).



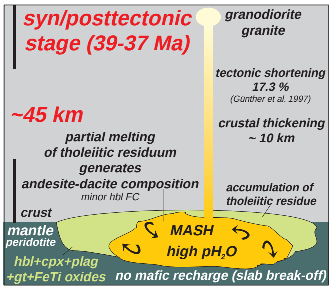


Fig. 15 and 16: Schematic petrologic evolution of arc magmatism in the Chilean Precordillera (21.5-26°S).
initial stage: wide compositional range is controlled by fractional crystallisation at low pH_2O, minor hbl and no garnet in the residual mineralogy. Continuous magmatic activity leads to accumulation of hbl-bearing tholeiitic residue and explain the increasing La/Yb-ratios in the Chilean Precordillera. Syn/posttectonic melts are generated mostly by remelting of accumulated hbl- and garnet bearing tholeiitic residue.

References

Döbel, R., Hammerschmidt, K., Friedrichsen, H., 1992, Implication of 40Ar/39Ar dating of Early Tertiary volcanic rocks from the north-Chilean Precordillera, Tectonophysics, 202, p. 55-81.
Günther, A., Haschke, M., Reutter, K.-J., Scheuber, E., 1997, Repeated reactivation of an ancient fault zone under changing kinematic conditions: The Sierra de Moreno Fault System (SMFS), N.Chilean Precordillera, VIII. Congr.Geol.Chil., Antofagasta, p.85-89.
Hildreth, W., Moorbath, S., 1988, Crustal contributions to arc magmatism in the Andes of Central Chile, Contrib.Mineral.Petrol., 98, p.455-489.
Heumann, A., Anthes, G., Wörner, G., in prep, Petrology and Geochemistry of Cretaceous to Tertiary intrusive rocks from the Chilean Andes (18°S - 22°S).
Kay, S.M., Maksaev, V., Moscoso, Mpodozis, C., Nasi, C., 1987, Probing the Andean lithosphere: mid-late Tertiary magmatism in Chile (29°-30°30'S) over the modern zone of subhorizontal subduction, J.Geophys.Res., 92, p.6173-6189.
Kay, S.M., Mpodozis, C., Ramos, V.A., Munizaga, F., 1991, Magma source variations for mid-late Tertiary magmatic rocks associated with a shallowing subduction zone and a thickening crust in the central Andes (28-33°S), in Harmon, R.S., Rapela, C.W. (eds.), Andean magmatism and its tectonic setting, Boulder, Colorado, Geol.Soc.Am.Spec.Pap. 265,p.113-137.
Kay, S.M., Mpodozis, C., Tittler, A., Cornejo, P., 1994, Tertiary magmatic evolution of the Maricunga Mineral belt in Chile, Int.Geol.Rev., 36, p.1079-1112.
Kramer, W., Bartsch, V. (submitted) The Mesozoic magmatic arc in Northern Chile: An outline of the geochemical evolution of volcanic sucsessions. - Revista Geologica de Chile; Santiago.
Maksaev, V., 1990, Metallogeny, geological evolution, and thermogeochronology of the Chilean Andes between lat. 21°-26°S, and the origin, of major porphyry copper deposits, unpubl. PhD dissert., 554 p., Dalhousie University, Halifax, Canada.
Martin, H., 1987, Petrogenesis of Archean Trondhjemites, tonalites and granodiorites from eastern Finland: major and trace element geochemistry, J.Petrol., 28, p.921-953.
Pardo-Casas, F., Molnar, P., 1987, Relative motion of the Nazca (Farallon) and South American plates since late Cretaceous time, Tectonics, 6, 3, p. 233-248.
Rollinson, H., 1993, Using geochemical data: evaluation, presentation interpretation, Longman Scientific Technical, Wiley & Sons, New York, 352 p.
Tepper, J.H., Nelson, B.K., Bergantz, G.W., Irving, A.J., 1993, Petrology of the Chilliwack batholith, North Cascades, Washington: generation of calc-alkaline granitoids by melting of mafic lower crust with variable water fugacity.
Williams, W.C., 1992, Magmatic and structural controls on mineralization in the Paleocene magmatic arc between 22°40' and 23°45' south latitude, Antofagasta, II.region, Chile, unpubl. PhD. thesis, U Arizona.