Modelling chemical weathering at river catchment scale: design and calibration of the WiTCh model

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A large number of small river catchments have been intensively studied over the last decades, for different purposes (such as the acidification of surface waters due to industrial activities). Long time series of data are available for these catchments, including the chemical composition of precipitation and stream at the catchment outlet, the characterization of mineralogy of soils and bedrock, the type of vegetation, the chemistry of the soil solutions.

These time series are of primary importance in terms of the building up and calibration of a mechanistic numerical model of the weathering processes applicable at the catchment scale. Many models describing the interaction between solutions and minerals are available. However, because of upscaling problems, those models cannot be applied at the catchment scale. Furthermore, existing models for weathering prediction in natural environment (such as SAFE) are limited to the description of the chemistry of the upper part of the soils and do not take into account the processes occuring deeper in the saprolith layer, where saturation respectively to primary minerals is often reached.

We present in this contribution an effort towards the building up of a numerical model describing the weathering processes from the surface down to the bedrock (the Weathering at The Catchment level model, WiTCh model). WiTCh is a multilayer model. It includes the calculation of the speciation of the soil solution (inspired from the SAFE model [e.g. Sverdrup et al, 1994)], but the base cation term is explicitely splitted into its K^+, Ca^{2+}, Mg^{2+}, Na^+ terms), and uses mechanistic laws for the dissolution of the primary minerals (François et al, WRI, 2001). The cationic exchange between the solution and the soil complex is calculated in a fully dynamic mode. This dynamic formalism allows the calculation of the budget for the aluminium in soil solutions in the WiTCh model, thus avoiding the calculation of the Al^{3+} concentration from an apparent equilibrium with a secondary phase (which is generally taken as gibbsite in other models). This innovation can lead to the mechanistic treatment of the secondary phases precipitation, including gibbsite.

Time series acquired on the Strengbach catchment (Vosges, France) by Probst and co-authors over 16 years are used to calibrate the WiTCh model. Model outputs will be compared to available data, and perspectives of application over larger catchments will be presented.

A reconstruction of the thermal history of the UHP Maksyutov Complex (South Urals) using ^{40}Ar/^{39}Ar-dating results

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The problem of formation of ultrahigh pressures in the Earth crust is one of the most intriguing ones in geosciences. One of the questions connected with it is an estimation of P-T-t retrograde path during exhumation of UHP metamorphic complexes. The peak pressure for the Maksyutov Complex, located in the southern part of the Main Uralian Fault zone, is estimated to be 15 - 20 kbar (up to 60 km deep)(Chesnokov & Popov, 1965, Dobretsov & Dobretsova, 1988).

A sample representing the contact between garnet-clinopyroxene-omphacite rock (OMP) and garnet glaucophanite (GL) (Lepezin et al., in press) was used for Ar/Ar step heating dating on phengite. Aliquots of phengite were taken across the contact throughout the distance of 19 cm. The obtained ages are shown in Fig. 1.

Fig. 1 Phengite ages across the sample

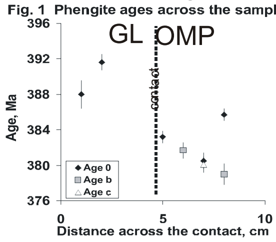
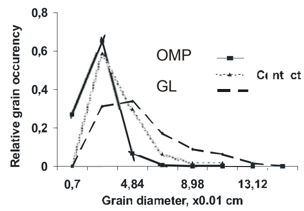


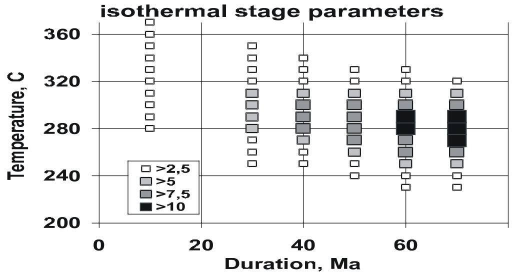
Fig.2 Phengite grain size distribution in the s m l



The age spectra turned out to be perfect, with plateau ages systematically changing from 392 to 379 Ma from GL to OMP. This discrepancy was attributed to different phengite grain size distributions, which were later determined by manual measurement of ~2000 grains (Fig. 2).

Using Fickian Ar^{40} diffusion equation and published T (t) constraints from fission track dating (Leech, 2000; Beane & Connelly, 2000) as the boundary conditions, age discrepancy between GL and OMP was calculated for obtained grain distributions using numerical modelling. It turned out that only a strongly non-linear cooling curve is capable of producing such a gap of 13 Ma. Non-linearity can be attributed either to a local re-heating impulse event, or to a cooling in several stages: fast for first 1-10 Ma, followed by slow or isothermal stage at 280±20 ^{0}C for 50-70 Ma, with linear cooling onwards.

Fig. 3 Age(OMP)-Age(GL) dependence n isothermal stage parameters



As there is no evidence for any intrusive activity near the sample location, the second model seems to be more viable.