Detrital illite crystals identified from crystallinite thickness measurements in siliciclastic sediments

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ABSTRACT

Illite crystals in siliciclastic sediments are heterogeneous assemblages of detrital material coming from various source rocks and, at paleotemperatures >70 °C, of superimposed diagenetic modification in the parent sediment. We distinguished the relative proportions of 2M1 detrital illite and possible diagenetic 1Md + 1M illite by a combined analysis of crystal-size distribution and illite polytype quantification. We found that the proportions of 1Md + 1M and 2M1 illite could be determined from crystallinite thickness measurements (BWA method, using the MudMaster program) by unmixing measured crystallinite thickness distributions using theoretical and calculated log-normal and/or asymptotic distributions. The end-member components that we used to unmix the measured distributions were three asymptotic-shaped distributions (assumed to be the diagenetic component of the mixture, the 1Md + 1M polytypes) calculated using the Galoper program (Phase A was simulated using 500 crystals per cycle of nucleation and growth, Phase B = 333/cycle, and Phase C = 250/cycle), and one theoretical log-normal distribution (Phase D, assumed to approximate the detrital 2M1 component of the mixture). In addition, quantitative polytype analysis was carried out using the RockJock software for comparison. The two techniques gave comparable results (r² = 0.93), which indicates that the unmixing method permits one to calculate the proportion of illite polytypes and, therefore, the proportion of 2M1 detrital illite, from crystallinite thickness measurements. The overall illite crystallinite thicknesses in the samples were found to be a function of the relative proportions of thick 2M1 and thin 1Md + 1M illite. The percentage of illite layers in I-S mixed layers correlates with the mean crystallite thickness of the 1Md + 1M polytypes, indicating that these polytypes, rather than the 2M1 polytype, participate in I-S mixed layering.

INTRODUCTION

Clay minerals contained in shale and sandstones undergo diagenetic and very low-grade metamorphic reactions when sedimentary basins subside in response to burial and/or tectonic loading. Reactions in clay minerals are irreversible under normal diagenetic and anoxic conditions, so that uplifted and exhumed sequences generally retain indices and fabrics indicative of maximum maturity and burial (Árkai 2002; Árkai et al. 2002). Clay minerals are mainly sensitive to temperature, and the use of illite-smectite (I-S) mixed layers as a “geothermometer” is generally accepted (Burst 1959; Hower et al. 1976; Pollastro et al. 2002). Clay minerals are mainly sensitive to temperature, and the use of illite-smectite (I-S) mixed layers as a “geothermometer” is generally accepted (Burst 1959; Hower et al. 1976; Pollastro et al. 2002). Nevertheless, other factors (e.g., heating rate, protolith, fluid composition, permeability, fluid flow) may control the illite enrichment of I-S mixed layers (Roberson and Lahann 1981; Colten-Bradley 1987; Pytte and Reynolds 1989; Hartmann et al. 1999).

Illite crystals in siliciclastic sediments in fold and thrust belt settings are heterogeneous assemblages of detrital material coming from various source rocks, and, at paleotemperatures >70 °C (Merriman and Kemp 1996), of superimposed diagenetic modifications of this sediment. Only diagenetic rather than detrital phases should be used to estimate paleotemperatures and to constrain the burial history of folded and thrust sedimentary successions that range in alteration intensity from diagenesis to low-grade metamorphism. In fact, detrital illite only records environments inherited from the past, generally of higher temperature, not directly related to the burial history of the sedimentary successions. Furthermore, in hydrocarbon exploration, illite studies are used to calibrate the heating history of sedimentary basin to ascertain that oil or gas generation from source rocks postdated trap formation (Peaver 1999). Hence, the extraction of quantitative information that distinguishes diagenetic illite from detrital micas is a great challenge for many clay mineral researchers.

Separation of detrital and authigenic illite crystals can be obtained by gravity separation in distilled water followed by ultracentrifugation. These grain-size separations can be improved by high-grade magnetic separations that permit the separation of authigenic, non-magnetic illite from detrital, more-magnetic micas that have the same particle size (Tellier et al. 1988). K-Ar dating of different grain-size fractions also can be interpreted to identify detrital and diagenetic phases (Peaver 1999). Other studies aimed at the same goal have been performed, for example, by Uhlik et al. (2000), who investigated the thickness distribution of illite crystals in diagenetically altered shales using...