

The conversion of smectite to illite during diagenesis: evidence from some illitic clays from bentonites and sandstones

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ABSTRACT. Diagenetic illitic clays from seven North American bentonites of Ordovician, Devonian, and Cretaceous ages and from three subsurface North Sea sandstones of Permian and Jurassic ages have been examined by X-ray diffraction (XRD) and transmission and scanning electron microscopy (TEM and SEM). XRD indicates that the clays from the bentonites are randomly and regularly interstratified illite/smectites (I/S) with 30-90% illite layers, whereas the clays from the Jurassic and Permian sandstones are regularly interstratified I/S, with 80-90% illite layers, and illite respectively. TEM of shadowed materials shows that randomly interstratified I/S consists primarily of mixtures of elementary smectite and 'illite' particles (10 and 20 Å thick respectively) and that regularly interstratified I/S and illite consist mainly of 'illite' particles 20-50 Å thick and > 50 Å thick respectively. Regularly interstratified I/S from bentonites and sandstones are similar with regard to XRD character and particle thickness distribution. These observations can be rationalized if the interstratified XRD character arises from an interparticle diffraction effect, where the smectite interlayers perceived by XRD, result from adsorption of exchangeable cations and water or organic molecules at the interfaces of particles generally < 50 Å thick. A neoformation mechanism is proposed by which smectite is converted to illite with increasing depth of burial in sedimentary rocks, based on dissolution of smectite particles and the precipitation/growth of 'illite' particles occurring within a population of thin phyllosilicate crystals.

KEYWORDS: smectite, illite, diagenesis, clays, bentonite, sandstone.

RECENT studies of some diagenetic interstratified illite/smectite (I/S) clays based on complementary use of transmission electron microscopy (TEM) and X-ray diffraction (XRD) have shown that the smectite layers detected by XRD actually represent the interfaces between particles consisting of only 1-3 silicate layers in thickness (McHardy *et al.*, 1982; Nadeau *et al.*, 1984a, b). Furthermore, the latter studies demonstrate that randomly interstratified I/S can be synthesized from mixed suspensions of elementary smectite and 'illite'

particles (10 Å and 20 Å thick respectively). The interstratified XRD phenomenon of these materials is thus an interparticle diffraction effect where water and organic molecules are adsorbed on the smectite-like interfaces within aggregates of thin phyllosilicate crystals. One objective of the present study is to assess the application of these concepts to illitic clays from bentonites and sandstones in greater detail.

Illitic clays in bentonites are currently accepted as being the products of a transformation process by which smectite layers, in response to increasing Al^{3+} for Si^{4+} tetrahedral substitution, collapse about selectively adsorbed interlayer K^+ ions thus forming illite layers (Hower *et al.*, 1976; Hoffman and Hower, 1979). The diagenetic conversion of smectite to illite is considered to be of general importance in the clay petrology of pelitic sediments. (Nadeau and Reynolds, 1981a; Eslinger and Sellars, 1981). In contrast, diagenetic illitic clays in sandstones are accepted as being the products of neoformation, i.e. precipitated from solution (Wilson and Pittman, 1977; Güven *et al.*, 1980). These clays are of great interest to the petroleum industry because of their deleterious effects on production from hydrocarbon reservoirs (Gray and Rex, 1966; Stalder, 1973; Pallatt *et al.*, 1984). The current situation is, therefore, that illitic clays in bentonites and sandstones are accepted as being formed during diagenesis but by different mechanisms, namely transformation in the case of bentonites and neoformation in the case of sandstones. Therefore, a second objective of this paper is to evaluate these hypotheses in the light of new experimental and analytical evidence.

Materials and methods. Ten samples of illitic clays (Table I) were Na-saturated and washed free of chloride. The < 0.1 µm fraction of samples WWB, CCB, NCB, and DIB and the < 0.2 µm fractions of SFB, MAG, LPB, RAN, TGB, and ROT were then isolated by centrifuga- tion. Sedimented aggregates of the suspensions were