Authigenic clay minerals in rock matrices and fractures from CRP-2 and CRP-3 cores (Antarctica)

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Summary Authigenic clay minerals have been identified through a scanning and transmission electron microscopy study in Oligocene sediments from CRP-2 and CRP-3 cores and in Devonian sandstones and in Jurassic dolerites in CRP-3 core (Ross Sea, Antarctica). Authigenic clay minerals in rock matrices and faults/veins in the Oligocene sediments in both cores consist mostly of dioctahedral smectites, rarely of berthierine/chlorite intergrowths, and illite. Al, K-rich smectites and kaolinite occur in the Devonian sandstones; trioctahedral smectites, berthierine/chlorite intergrowths, and Fe-hydroxides develop in the altered dolerites. These data indicate that the composition of the secondary phases depends on the geochemistry of the rock they grow in. Within each sample, the same authigenic minerals form in the matrix and in the vein/fault. Textures indicate that clays precipitated from fluids which circulated in the system during contemporaneous diagenetic and faulting events that affected the sedimentary sequences recovered in CRP-2 and -3 cores.

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Introduction

Clay minerals in drill core sequences can be powerful tools for documenting post-depositional processes during diagenesis. The Cape Roberts Project (CRP) obtained three cores (Cape Roberts Science Team, 1998; 1999; 2000) on the western margin of the West Antarctic Rift System (Victoria Land Basin, Ross Sea, Antarctica). Previous authors (Ehrmann, 1998; Setti et al., 1998, 2000, Ehrmann et al., 2005) interpreted smectites from CRP-1 and CRP-2 cores to be detrital. Setti et al. (2001) and Wise et al. (2001) investigated smectites in CRP-3 core: they interpreted flaky Fe-Al rich beidellites as detrital, hairy Mg-rich saponite as authigenic. *In situ* textural investigations led Wise et al. (2001) to interpret smectites occurring as grain coatings in sandstone lithologies to be early authigenic precipitates.

The present study aims to clarify the nature and origin of the clay minerals in CRP-2 and CRP-3 (Figure 1) cores and to provide complementary data for the characterization of the microfault patterns in the cores.

Discussion

Representative samples have been chosen throughout the cores (Table 1). Authigenic clays have been distinguished on the basis of their mode of occurrences which are: coatings on detrital grains, alteration products on pristine minerals such as detrital muscovite or magmatic phases, fillings in pores within the rock matrices and in the faults/veins and dykes. Figure 1 comprises four representative back scattered-scanning electron microscopy (BSE-SEM) images for each type of occurrence.

Figure 1a shows saponite crystals which grow perpendicular to detrital quartz grains in the clastic dyke at 790.37 mbsf, located immediately above the shear zone in CRP-3 core. Figure 1b shows smectites (saponite) which form as alteration products on magmatic plagioclases in a dolerite sample (796.64 mbsf) from CRP-3 core. Figure 1c shows smectite flakes (beidellite-montmorillonite) growing in pores between detrital grains in sample 579.49 mbsf from CRP-2 core. Figure 1d shows a vein in sample 523.84 mbsf (CRP-2 core) filled with smectite crystals of the beidellite-montmorillonite series.

Dioctahedral phyllosilicates occur in the Oligocene glacio-marine sedimentary rocks in both cores. Ca-Mg-rich trioctahedral smectites, rare berthierine/chlorite intergrowths and Fe-hydroxides (and probably Al-hydroxides) form in the altered dolerites in the lower part of the core. The Beacon sandstones show K-Al-rich smectites and kaolinite as newly formed clays (Figure 2).

A mixed clay mineral assemblage (saponite and montmorillonite-beidellite) occurs in two samples from the top and at the bottom of a major shear zone (790.37 and 804.69). Sample 790.37 is a clastic dyke that cuts a dolerite clast in this zone; Fe-rich dioctahedral smectites (assemblage 1) form on pyroxenes and in the dolerite matrix; saponite (assemblage 2) form inside the clastic dyke. Assemblage 1 is probably due to a peculiar chemical composition of the system; saponite in assemblage 2 is probably due to fluids linked to the shear zone which affects dolerite. Sample 804.69 is a sandstone cut by veins filled with clay material and dolerite fragments. The mixed clay mineral assemblage is probably due to the interaction between an Al-rich system (the sandstone), Mg-Fe-rich fluids and rock fragments linked to the overlying sheared dolerite.

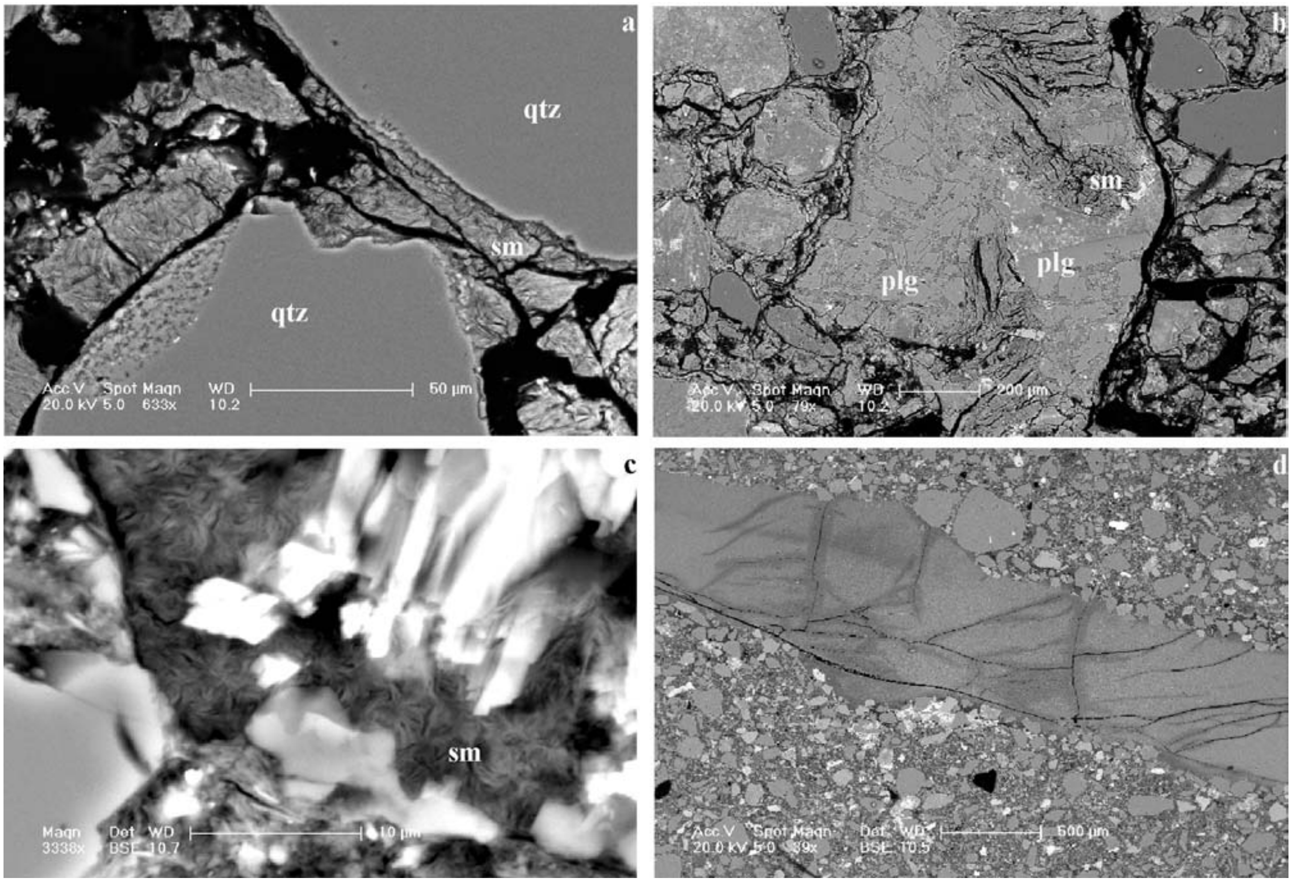

Figure 1. a: smectites growing as coatings of detrital quartz (qtz) grains. b: smectites growing as alteration of plagioclase (plg) in dolerite. c: smectites growing in pores between detrital grains. d: smectites growing a vein.

Texture and composition of authigenic clays do not change between clay minerals in rock matrices and those in fractures. The characteristics of the authigenic clays indicate that they precipitated from circulating fluids, although their chemical composition also depends on the chemical composition of the host rock system they form in.

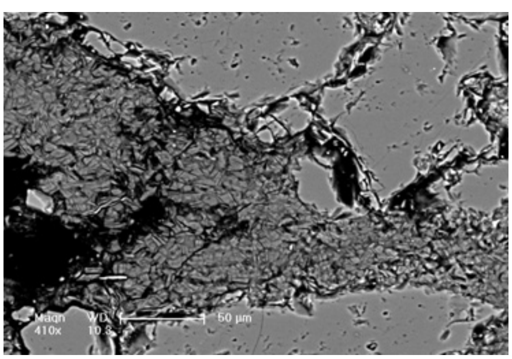

Figure 2. BSE-SEM image of kaolinite crystals growing between quartz grains in a Beacon sandstone (CRP-3).

K-rich dioctahedral smectites dominate the newly-formed clay assemblages in Oligocene sediments and Beacon sandstones. On the contrary, Ca-Mg rich smectites form in the mafic chemical system of dolerites and in dykes and veins linked to the shear zone. Authigenic clay minerals formed contemporaneously from the same fluids which circulated during the diagenetic and faulting events.

The similarity of authigenic clay mineral characteristics in rock matrices and fractures *s.l.* (i.e. faults/veins, clastic dykes) support the hypothesis by Wilson and Paulsen (2001) that faulting in the Oligocene sequences from CRP-2 and CRP-3 was early and synchronous with lithification.

Summary

Our data indicate that authigenic clay minerals do occur in all the analyzed samples from the Oligocene sedimentary rocks, the shear zone and the basement rocks. Moreover clays have been interpreted as authigenic on the basis of detailed observation of textural characteristics, with their composition being determined by the chemistry of the local environment. The similarity between authigenic minerals in the matrix and in the veins and faults is an evidence that clays precipitated from fluids circulatig in the system during contemporaneous diagenetic and faulting events.

Table 1. Studied samples with authigenic clay minerals

CRP-2 sample depth (mbsf)	**Authigenic clay minerals (by SEM)**	**CRP-3 sample depth (mbsf)**	**Authigenic clay minerals (by SEM, TEM)**
Oligocene sediments		Oligocene sediments	
328.44	(K)montmorillonite-beidellite	52.65	(K) montmorillonite-beidellite, illite, biotite, chlorite
357.44	(K)montmorillonite-beidellite	112.37	(K) montmorillonite-beidellite, illite, biotite, chlorite
523.84	(K)montmorillonite-beidellite	142.89	(K) montmorillonite-beidellite
542.83	(K)montmorillonite-beidellite	159.93	(K) montmorillonite-beidellite
579.49	(K)montmorillonite-beidellite	166.65	Mg-rich montmorillonite-beidellite, illite, biotite, chlorite, berthierine
623.95	(K)montmorillonite-beidellite	250.50	(Na, K) montmorillonite-beidellite, illite, chlorite
		538.81	(Na) montmorillonite-beidellite, illite, chlorite
		Shear zone rocks	
		790.37	montmorillonite-beidellite, saponite
		796.64	saponite
		797.42	(Ca) saponite, chlorite, berthierine, Fe-oxides
		Basement rocks	
		804.69	montmorillonite-beidellite, saponite, kaolinite
		810.56	saponite
		821.12	(Ca) saponite, chlorite, berthierine, Fe-oxides
		823.29	(K) montmorillonite-beidellite
		845.37	(K) montmorillonite-beidellite, illite

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References

Cape Roberts Science Team (1998), Studies from the Cape Roberts Project, Ross Sea, Antarctica. Initial report of CRP-1, Terra Antartica, 5 (3), pp 713.

Cape Roberts Science Team (1999), Studies from the Cape Roberts Project, Ross Sea, Antarctica. Initial report of CRP-2/2A, Terra Antartica, 6 (1/2), pp 173.

Cape Roberts Science Team (2000), Studies from the Cape Roberts Project, Ross Sea, Antarctica. Initial report of CRP-3, Terra Antartica, 7 (1/2), pp 209.

Ehrmann W.U. (1998), Lower Miocene and Quaternary clay mineral assemblages from CRP-1, Terra Antartica, 5, 613-619.

Setti, M., L. Marinoni, A. Lopez-Galindo, and A. Ben Aboud (1998), TEM observations and rare earth element analysis on the clay minerals of the CRP-1 core (Ross Sea, Antarctica). Terra Antartica, 5, 621-626.

Ehrmann W.U., M. Setti, and L. Marinoni (2005), Clay minerals in Cenozoic sediments off Cape Roberts (McMurdo Sound, Antarctica) reveal paleoclimatic history, Palaegeograhy, Palaeoclimatology, Palaeoecology, 229, 187-211.

Setti, M., L. Marinoni, A. Lopez-Galindo, and A. Delgado-Huertas (2000), Compositional and morphological features of the smectites of the sediments of the CRP-2A core (Ross Sea, Antarctica), Terra Antartica, 7, 581-587.

Wilson, T.J., and T.S. Paulsen (2001), Fault and fracture patterns in CRP-3 core, Victoria Land Basin, Antarctica, Terra Antartica, 8, 177-196.

Wise, S.W., J. Smellie, F.S. Aghib, R. Jarrad, and L. Krissek (2001), Authigenic smectite clay coats in CRP-3 Drillcore, Victoria Land Basin, Antarctica, as possible indicators of fluid flow: a progress report, Terra Antartica, 8, 281-298.