Burial Diagenesis of Clay Minerals in a Well in the Niigata Sedimentary Basin, Japan

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1. INTRODUCTION

The most important diagenetic clay change during burial is a progressive transformation of smectite minerals; di-octahedral smectite transforms into illite via interstratified illite/smectite (I/S) (Hower et al., 1976; Son and Yoshimura, 1997), and tri-octahedral smectite changes into chlorite via interstratified chlorite/smectite (C/S) (Chang et al., 1986; Beaufort et al., 1997).

The purpose of the present study is to document the clay mineral diagenesis observed in a hydrocarbon exploration well in the Niigata sedimentary basin that penetrates a sedimentary succession of 4,820 m. The present study shows that the well displays C/S diagenesis as well as I/S with increasing burial depth.

2. MATERIALS AND METHODS

Cutting samples were taken at uniform intervals of 200 m from the well. Mudstones for examination were carefully hand picked from the cuttings. Mineralogical and chemical examinations were made by XRD and Electron microprobe on clay fractions in the mudstone cuttings. Bulk rock analyses were done by XRF and Rock-Eval.

3. RESULTS

Samples from depths of 1,200-2,000 m are characterized by the occurrence of di-octahedral smectite as shown in Fig. 1. Randomly interstratified illite/smectite (R=0 I/S) occurs at depths of 2,800 m and 3,000 m. At depths below 3,400 m, randomly interstratified illite/smectite disappears and R=1 ordered illite/smectite occurs. There is a tendency for illite layers in the ordered illite/smectite to increase with increasing burial depth.

Tri-octahedral smectite (saponite) occurs markedly at depths of between 2,200 m and 2,600 m. The 060 reflection of this mineral appears at 1.537 Å and therefore indicates tri-octahedral type. Chemically, the tri-octahedral smectite is characterized by a high content of Al and Fe. A regularly ordered (1:1) chlorite/smectite (C/S), which is usually referred to as corrensite, occurs at a depth of 3,200 m of the study well.

Chemical composition of I/S apparently varies with depth in SiO2, Al2O3, and K2O contents from the shallower depths to the greater depth, although in the middle depths there are no chemical data. In response to increasing burial depth, potassium and aluminum contents increase, while silica content decreases. Illite layers in illite/smectite also increase proportionally with increasing depth of burial as described above. Accordingly, this chemical result indicates a chemical transformation of illite/smectite; this variation with depth demonstrates that the substitution of Al for Si in tetrahedral sheet is compensated for by the addition of K to interlayers.

It should be noted that di- and tri-octahedral clay mineral phases occur alternately throughout the well (Fig. 1). Di-smectite (montmorillonite) and tri-smectite (saponite) are present in the upper interval: the di-smectite at depths of 1,000-2,000 m and the tri-smectite at depths of 2,200-2,600 m. Considering lithology, it is likely that the well sediments have altered diagenetically from two different volcanic materials: the sediment derived from acidic volcanic materials at depths of less than 2,000 m and the sediment derived from basic Mg-Fe volcanic materials at 2,200-2,600 m. As the depth of burial increases, the di-smectite changes to interstratified illite/smectite (I/S) at 2,800-3,000 m and 3,400-4,820 m, whereas the tri-smectite converts its phase into a 1:1 regularly interstratified chlorite/smectite (C/S) at a depth of 3,200 m. Throughout the whole interval, as a consequence, I/S and C/S transitions are recognized alternately: S→I/S→I and S→C/S→C.

The first occurrence of the C/S appears at the same depth of about 3,200 m as the conversion of randomly interstratified I/S to R=1 ordered I/S. Furthermore, the depth is consistent with a Tmax temperature of 435℃, which implies a subsurface paleotemperature of about 100℃. The clay mineral diagenesis in the study well confirms the fact that I/S and C/S can act as geothermometers in clastic and pyroclastic sediments.

4. CONCLUSION

The study well of the Niigata sedimentary basin is characterized by an alternate diagenetic change of di- and tri-octahedral clay minerals with increasing burial depth. In the well, the reaction of the di-octahedral smectite to illite is a somewhat continuous series of interstratified illite/smectite: the proportion of illite layers in the interstratified illite/smectite increases with increasing temperature in response to increasing depth.

In comparison, the tri-octahedral smectite reaction is a prograde sequence of the three phases: smectite, corrensite (1:1 C/S), and chlorite. In other words, corrensite is considered as a discrete phase, rather than interstratified smectite and chlorite layers.

5. REFERENCES

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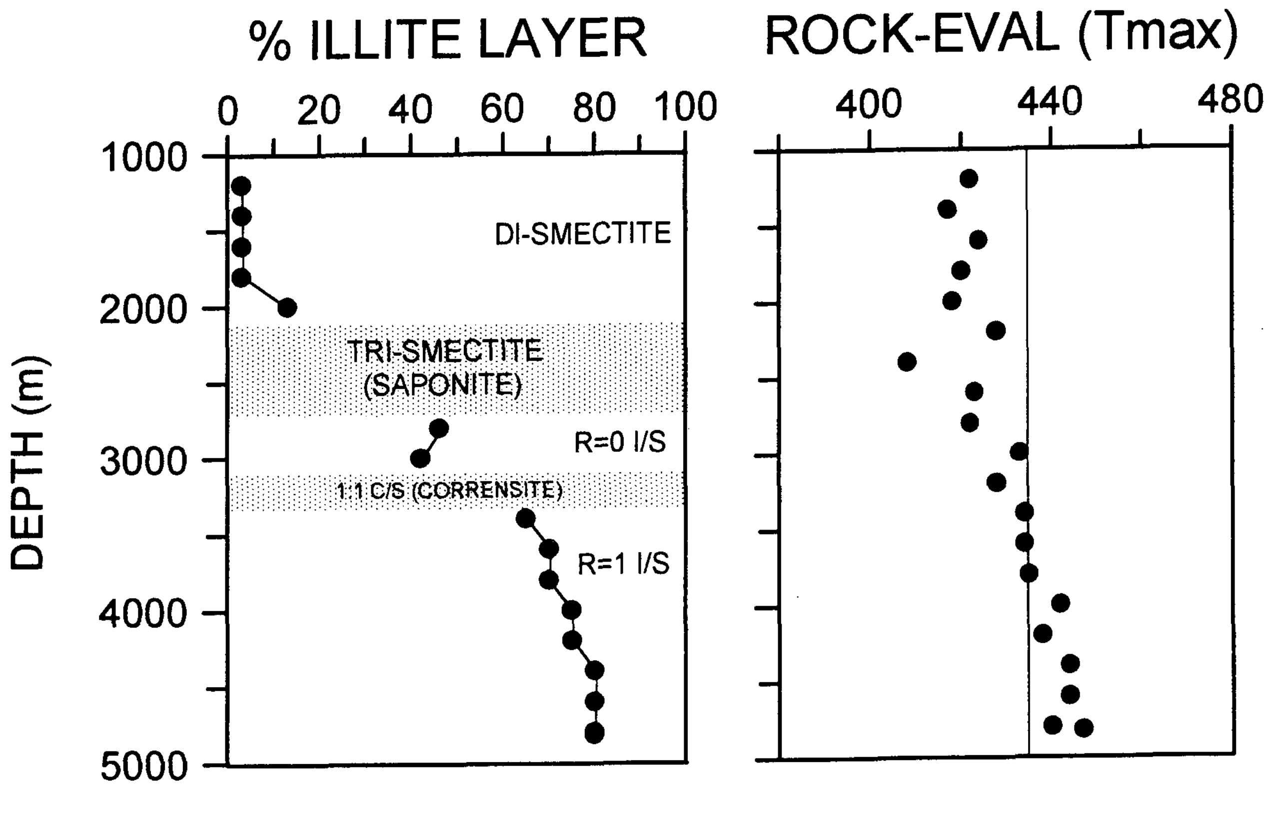

Fig. 1. Clay mineralogical changes and Tmax with burial depth.