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SHORT COMMUNICATION

Discovery of the Ordovician Kinnekulle K-bentonite at the Põõsaspea cliff, NW Estonia

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Abstract. A previously unknown outcrop of the Kinnekulle K-bentonite (metabentonite) is reported from the Põõsaspea cliff, NW Estonia. The bed has a sharp lower and a gradational upper contact and comprises ca 28 cm of clay overlain by ca 10 cm of hard K-feldspar-rich variety. The latter contains a layer of breccia, which indicates early onset of recrystallization and hardening of volcanic material. The discovery shows that the Põõsaspea cliff section is younger than previously thought and includes rocks of both Haljala and Keila stages.

Key words: Kinnekulle K-bentonite, metabentonite, Ordovician, Keila Stage, Baltoscandia.

The Kinnekulle K-bentonite (or metabentonite) is the thickest and most widely distributed altered volcanic ash bed in the Ordovician of Baltoscandia (Bergström et al. 1995). As an outstanding stratigraphical marker it has been widely used in stratigraphy for defining the base of the Keila Regional Stage (Männil 1958; Hints & Nõlvak 1999). In the eastern Baltic area the Kinnekulle Bed was hitherto known to crop out only in the Pääsküla section near Tallinn (Hints et al. 1997). Recent field-work in coastal cliffs of NW Estonia revealed another exposure of this bed at Cape Põõsaspea. Although mineralogical, geochemical, and micropalaeontological investigations will still follow, we consider it important to present some preliminary data of the discovery.

The up to 2 m high and ca 800 m long NW–SE directional cliff on the eastern coast of Cape Põõsaspea exposes a succession of limestones with varying contents of clay and bioclastic material. The locality was well known already to Schmidt (1881) and Öpik (1934). Starting from the latter study, the section has been included to the Jõhvi Substage of the Haljala Stage, or more precisely to the lower part of the Jõhvi Substage (Rõõmusoks 1970).

A nearly 40 cm thick K-bentonite composed of plastic clay and hard feldspathitic layers crops out at, and slightly above the sea level, about 100 m NW from the SE end of the cliff (59°13′27.3″ N, 23°31′40.8″ E; Fig. 1A). The lower part of the bed contains abundant phenocrysts of biotite, which are considered to be indication of volcanic origin. The thickness of the disclosed bed corresponds to that of the Kinnekulle Bed in NE Estonia (Vingisaar 1972). Other K-bentonites in this stratigraphical interval are much thinner (Bergström et al. 1995, fig. 5), leaving no doubt that the bed in question is the Kinnekulle Bed.

Due to southward dip of layers reaching some 1.5 m in 100 m, the spatial extent of the K-bentonite is limited to about 40 m along the low cliff. The clayey part of the bed is mostly covered by sand and pebbles, and hence digging is necessary to reveal its full thickness. Moreover, the accessibility of the bed depends on the stand of the sea level. These are likely the reasons why the Kinnekulle Bed has remained unnoticed by earlier students of the Põõsaspea cliff. However, Rõõmusoks (1970, p. 188) reported biotite-rich pieces of K-bentonite on the coast and suggested that they were derived from an older bed at the lower boundary of the Jõhvi Substage that is exposed below the sea level.

During this study the Kinnekulle Bed was uncovered in three sites, two of which, 6 m apart, are shown in Fig. 1D. The succession of the K-bentonite and its overlying strata from base to top is as follows (Fig. 1B):

(1) 2–5 cm of dark greyish plastic clay containing hard particles. The basal contact with underlying limestones of the Jõhvi Substage is sharp.
(2) 2–3 cm light grey, in places yellow, hard layer of uneven distribution (not revealed in site 1); its topmost part is very rich in large biotite phenocrysts.
(3) 21–23 cm of light grey (almost white when dry) plastic clay. From ca 10 cm from the base it contains an up to 3 cm thick hard discontinuous layer. The

clay also embodies irregularly distributed rounded and flattened almost white nodules of hard variety, up to 10 cm in size, which seem to be more common in the upper 10 cm of the clay. Some nodules display microlamination resulting from varied content of biotite; sometimes they are bioturbated, burrows are filled with darker material. Angular hard particles are also encountered within the clay.

(4) 5–7 cm light yellowish to brownish hard feldspathitic layer, occasionally containing elongated or irregularly shaped concretions of pyrite reaching 5 cm in size, bioturbated in places. The topmost 0.5–3 cm is a distinct breccia with greyish cement containing angular particles from sub-mm to 7 mm in size. The clasts are mostly lighter in colour; no size gradation can be observed. The lower contact of the breccia is irregular, whilst the upper surface is mostly flat and more distinct (see Fig. 1C). Individual layers of this interval are lenticular and their thickness and colour vary over short distances.

(5) 2–3 cm darker brownish and slightly carbonaceous rock, with abundant brachiopod shells and fragments in the upper part. The upper contact of this layer is wavy.

(6) 10–14 cm greyish-brown to dark brown bituminous mudstone containing accumulations of shelly faunas in the lower part and microlaminated, seemingly bituminous rock in the upper part.

(7) 20+ cm wavy bedded limestone with marly intercalations and rich shelly faunas.

The lower contact of the Kinnekulle Bed is sharp. The composition of the basal darker clay layer nevertheless needs further study to confirm its volcanic origin and undisturbed setting. The upper limit of the K-bentonite is more difficult to define. The breccia layer at about 35 cm from the base is devoid of carbonate material. A few centimetres above it the volcanic material is redeposited, mixed with carbonate mud, and fossils become abundant. Awaiting mineralogical analysis, we tentatively draw the upper boundary of the K-bentonite within bed 5 below the appearance of abundant faunas at ca 38 cm from the base. It cannot be excluded, however, that also some overlying strata below the normal limestones contain material of volcanic origin.

The outcrop of the Kinnekulle Bed at Põõsaspea deserves attention for several reasons.

Firstly, the K-bentonite bears information about the depositional environment and early diagenetic alteration of the ash bed. For instance, the above described breccia layer in the upper hard part of the bed indicates active hydrodynamics. It also evidences that parts of the ash bed started to (re)crystallize and harden rather rapidly so that angular clasts could be produced well before the carbonate sedimentation was re-established. This in turn implies an important role of sea water and its chemistry in the initial alteration of the ash. Early formation of authigenic silicates in the Kinnekulle Bed has been suggested by Kiipli et al. (2007).

Secondly, the Põõsaspea cliff constitutes an excellent locality to study palaeoecological consequences of a large ash-fall. It has been shown previously that this environmental perturbation had severe impact on several fossil groups, ostracodes in particular (Hints et al. 2003). In the Pääsküla locality, the Kinnekulle Bed appeared to contain abundant scolecodonts (Hints et al. 1997); in Põõsaspea, however, the plastic clay turned to be barren of organic-walled microfossils. As of now the reasons for this discrepancy cannot be fully explained.

From the stratigraphical point of view the discovery of the Kinnekulle Bed at the Põõsaspea cliff allows us to re-interpret the age of the section as being younger than previously thought and representing both Haljala and Keila stages.

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REFERENCES

Bergström, S. M., Huff, W. D., Kolata, D. R. & Bauert, H. 1995. Nomenclature, stratigraphy, chemical fingerprinting and areal distribution of some Middle Ordovician K-bentonites in Baltoscandia. *GFF*, **114**, 327–334.

Hints, O. & Nõlvak, J. 1999. Proposal for the lower boundary-stratotype of the Keila Regional Stage (Upper Ordovician). *Proceedings of the Estonian Academy of Sciences, Geology*, **48**, 158–169.

Hints, O., Kallaste, T. & Kiipli, T. 1997. Mineralogy and micropalaeontology of the Kinnekulle altered volcanic ash bed (Ordovician) at Pääsküla, North Estonia. *Proceedings of the Estonian Academy of Sciences, Geology*, **46**, 107–118.

Hints, O., Hints, L., Meidla, T. & Sohar, K. 2003. Biotic effects of the Ordovician Kinnekulle ash-fall recorded in northern Estonia. *Bulletin of the Geological Society of Denmark*, **50**, 115–123.

Kiipli, T., Kiipli, E., Kallaste, T., Hints, R., Somelar, P. & Kirsimäe, K. 2007. Altered volcanic ash as an indicator of marine environment, reflecting pH and sedimentation rate – example from the Ordovician Kinnekulle bed of Baltoscandia. *Clays and Clay Minerals*, **55**, 177–188.

Männil, R. 1958. Grundzüge der stratigraphie der Keila-stufe (Ordovizium, Estland). *Eesti NSV Teaduste Akadeemia Toimetised. Tehnilise ja Füüsikalis-Matemaatiliste Teaduste Seeria*, **7**, 235–246 [in Russian, with German summary].

Öpik, A. 1934. Über Klitamboniten. *Acta et Commentationes Universitatis Tartuensis*, ser. A, **26**, 1–239.

Rõõmusoks, A. 1970. *Stratigraphy of the Viruan Series (Middle Ordovician) in Northern Estonia*. Valgus Publishers, Tallinn, 346 pp. [in Russian, with English summary].

Schmidt, F. 1881. Revision der ostabaltischen silurischen Trilobiten nebst geognostischer Übersicht des ostbaltischen Silurgebiets. Abt. I. Phacopiden, Cheiruriden und Encrinuriden. *Mémoires de l'Academie Impériale des Sciences de St.-Petersbourg*, ser. 7, **30**, 1–238.

Vingisaar, P. 1972. On the distribution of the main metabentonite stratum (d; XXII) in the Middle Ordovician of Baltoscandia. *Eesti NSV Teaduste Akadeemia Toimetised, Keemia, Geoloogia*, **21**, 62–70 [in Russian, with English summary].

Kinnekulle K-bentoniidi paljand Põõsaspea pangal (Loode-Eesti)

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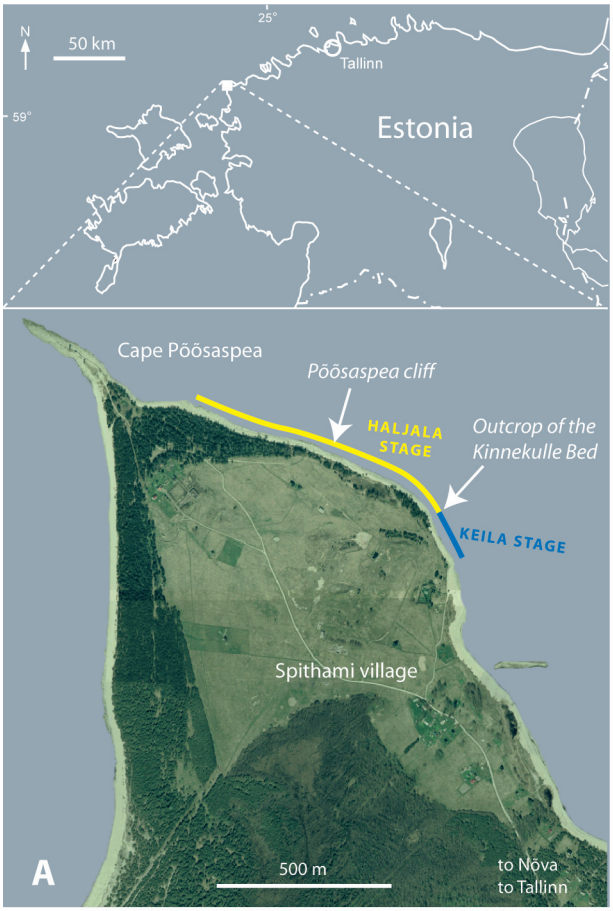
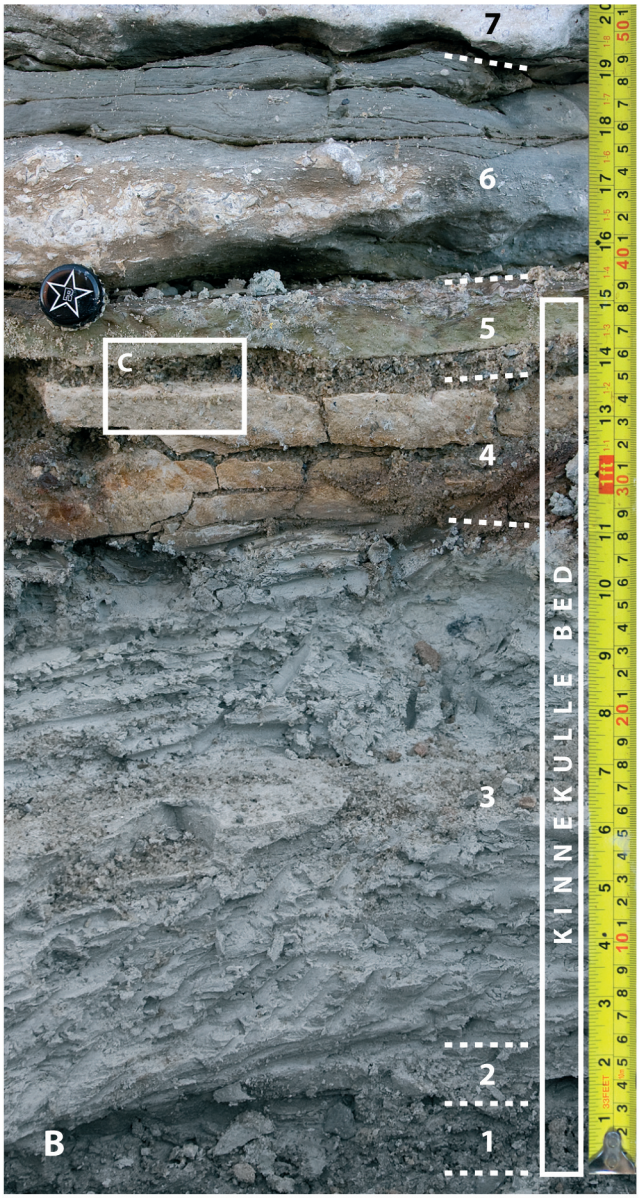
On kirjeldatud Kinnekulle K-bentoniidi seniteadmata paljandit Põõsaspea neeme idarannikul. Kiht koosneb umbes 28-sentimeetrisest savikast ja 10-sentimeetrisest kõvast kaaliumpäevakivirikkast erimist. Viimases sisalduv bretšakiht tõendab vulkaanilise tuhakihi teatud osa kiiret kõvastumist. Keila lademe alumist piiri markeeriva kihi leidmine näitab ühtlasi, et läbilõikes paljanduvad kivimid on seniarvatust nooremad.

Fig. 1. (A) Locality map. (B) Cross-section of the Kinnekulle Bed and overlying strata, combined from sites 1 and 2 shown in Fig. 1D; numbered layers are described in the text. (C) Detail of B showing breccia within the uppermost feldspathitic layer of the Kinnekulle Bed. (D) View of the outcrop showing two sites where the bed was uncovered. Photos by R. Hints and O. Hints; aerial photo from the Estonian Land Board (http://xgis.maaamet.ee).


N
50 km
25°
59°
Tallinn
Estonia
Cape Põõsaspea
Põõsaspea cliff
HALJALA STAGE
Outcrop of the Kinnekulle Bed
KEILA STAGE
Spithami village
A
500 m
to Nõva
to Tallinn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6
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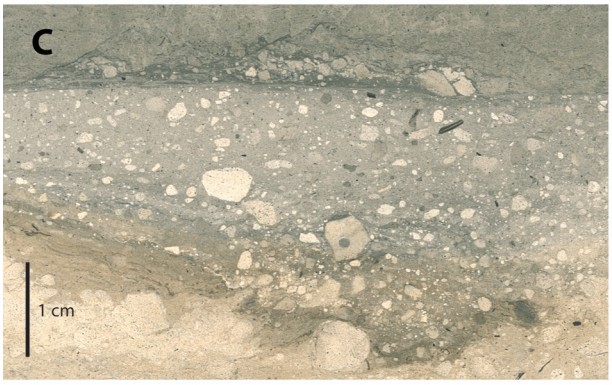
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