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INITIAL SOIL FORMATION ON MINING DEPOSITS. A PRELIMINARY REPORT

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Abstract: ***Initial soil formation on mining deposits. A preliminary report.*** A tailing pond of a lead and zinc mine in the Eastern Romanian Carpathians near Rodna was investigated for its features of soil formation and stabilisation. A series of orientated soil samples were taken and analysed for there structure and soil surface development. These samples exposed the phenomena of PSO (pellicular surface organisation) on the bare mining spoils, which are comparable to the soils development around sebkhas in seminarid regions. A biological organisation starts very soon. In some parts it already reached to the formation of an A_h-horison and thus to the dynamic of forest soils such as rankers. The colonisation of grasses and *Hippophae* showed to best adapted to protect against deflation and linear soil erosion. Linear soil erosion on slopes is not an active geomorphological process yet. But the fragility of the system could occur, in case of aggressive pressure over the components of the system, the activation of linear and areal erosional processes.

Key words: mining deposits, soil formation, soil erosion, stabilisation, Eastern Carpathians.

Introduction

The Water Frame of the European Union (EU 2000) claims the preservation of a good ecological situation of any catchment's area as well as its amelioration. The Baia Mare-Aurul accident in 2000 highlighted the precarious situation of the mining areas in the Carpathian region (UNEP-OCHA 2000, SCHULZ et al. 2005). Thus, the various spoil deposits in these mining areas are necessarily to stabilise and to protect against any kind of soil erosion in order to avoid a groundwater contamination of their surroundings. On this background investigations on soil and soil surfaces development are conducted on a tailing pond near Rodna, Upper Somes Valley (Romania). The aim of these investigations is to find autonomous processes of soil stabilisation and regeneration on artificial and highly polluted deposits. There also is the question of an exploitation of these processes to stabilise such deposits against deflation and soil erosion. Sampling for soil structure was done in October 2006 and March 2007 in order to establish an inventory of the structure of the upper soil layers and surface types. In this article we will present the first results on soil surface structure development as well as on linear soil erosion on the Anies/Rodna tailing pond.

The setting

Rodna belongs to the oldest mining regions in the Carpathians. It takes part of the transition zone from the inner volcanic belt to the crystalline zone of the Eastern Carpathians. Whereas the exploitation of silver was the main activity in medieval time the recent activities concentrated on leads and zinc bearing ores. In the late 1970ies a flotation plant was erected on the Somes terrace west of Rodna town. At the same time a tailing pond was build up on the widening terrace of Somes river west of the flotation plant. The

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ores generally originate from two regions: a grey deposit comes from the Valea Mare region east of Rodna. It contains about 0.12% Zn, 0.06% Pb, 1.5-2.0 % S, 0.26% Mn, 1.02% Ti and 3.41% Fe. Red and sulphur rich tailings originate from the Valea Minului area north of Rodna. Whereas their content of zinc and lead is comparable to the Valea Mare tailing, sulphur may climb up to 24 %. This certainly is due to the employment of $CaSO_4$, CaOH and $ZnSO_4$ during the flotation process (Kottler frdl. communication). These ores were grounded to sand, silt and clay. The suspension of tailings was transported to a 7.5 ha large pond with about 10 terraces and an elevation of 20 m over ground. About 3,6 mio tons were deposited behind a dam made of fluvial material parallel to the Somes bench. Figures 1 and 2 explain the situation of the tailing pond in an intensively exploited agrarian environment in the middle an upper mountain forest zone of the Eastern Carpathians. The pond was active up to 1993. In 1998 the whole construction was mainly uncovered and there was a pool covering about one third of the surface near the slope. At present the mining activities of the Rodna region are closed down, but the tailing pond is properly maintained. About the half of the surface is covered by bushes and trees mainly *Hippohae rhamnoides, Alnus glutinosa, Robinia pseudacacia, Salix gracilis, Pinus nigra* etc. The outer slopes are partly covered with grasses like *Festuca* r*ubra*, *Dactylis glomerata* or *Agrostis tenuis* (see also Cristea et al 1995).

Measurements after the deposition of the tailings.

Already during the first construction period deflation was a great problem and lead to protests of the population**.**

Thus there were some attempts of soil cover by alluvial material, an experimental planting of grasses in a cross wise arrangement of the upper walls as well as tree planting *Alnus* on the plain near the pond and *Robinia, Salix Picea* etc on the terraces and also sawing of forbs on some terraces. Since 1987 investigations were conducted in order to follow the bacterial and enzymatic activities of an initial soil development (Kiss et al. 1992, Pasca et al. 1994, 1998, 2000). Experimental plots were installed on several terraces. These experiment comprised different soil covering with slope material and farm manure, sowing of forbs and grasses as well as tree planting. Enzymatic activities were measured during the following years and showed only in sites of soil covering and fertilising a notable soil development. Comparable investigations were done in The Apuseni Mountains (Fodor et al. 2003)

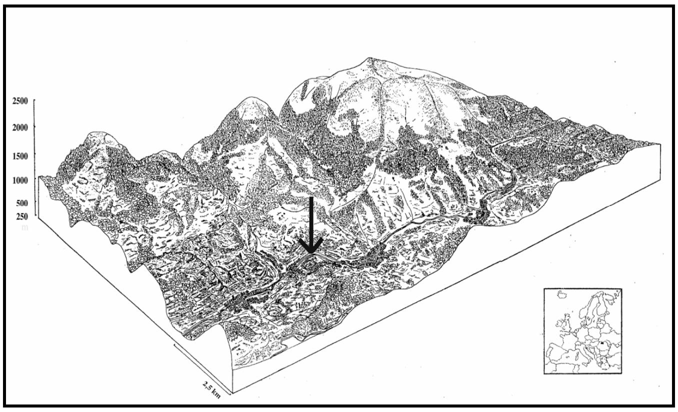

Fig. 1 Rodna Mountains and the Upper Somes valley with the Anies/ Rodna tailing pond
(from Schulz et al. 2005 modified)

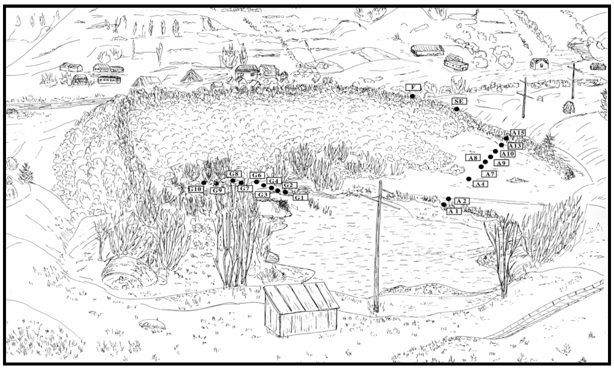

Fig. 2 The Anies/Rodna tailing pond in 2007 with the location of soil samples.

To minimise the deflation on the ponds surface about the half of the surface were covered with alluvial soil material. Finally the surface presents a mosaic of bare tailings, a thin cover of alluvial soil material as well as some lumps of it. From about 2000 on groups of *Alnus* were planted around the pool, *Hippophae* in some stripes on the surface and *Robinia* on the surrounding walls. Fig. 3 shows that both *Alnus* and *Hippophae* worked very well by now covering more than half of the ponds surface.

Investigations on soil structure and surfaces.

The soil development on these of heavily polluted deposits shall be evaluated by the structure of the upper centimetres and of the different surface types. Thus one may wait the stages of mineral organisation and structuring and

those of biological development. They will allow an evaluation of the dimension and necessary time of these developments.

In October 2006 and march 2007 structure samples were collected along several transects from the margins of the pool on heading for the edges of shrubs on the plain or on the outer walls. They cover all types of sediments and vegetation. The samples were analysed under the stereomicroscope and documented.

Here we present two transects on the bare material and on vegetated ground as well as on one outer terrace with experimental tree planting. The location of the samples is indicated on figures 3 and 6.

First results

A Transects of the surface of the pond

1. Developments on the bare tailings

The transect A was taken in march 2007 and covers the bare tailings on the eastern part of the ponds surface (cf. Fig. 3). The samples were taken along a straight line from the bench of the pool to the outer walls of the pond.

A1 Margin of the pool. Red material from Valea Minului (7.5 YR 5/8). Silty clay, dense and non structured. Smooth sintered surface with a sealing. Sufrosion and insect hollows. worm traces also on the surface

A2 10m. Dense homogeneous clay-silt with some reduction plets (7.5YR5/8, 7.5YR 7/3) In the lower part slightly more coarse material. Surface about 1 mm sintered, bare and smooth with some flakes. Cracks and sufrosion hollows. Worm hollows.

A4 41m. Island in the plaque material, about 5 cm elevated with a sparse moss cover Some grasses (*Festuca, Dactylis).* Surface bare and smooth with little cracks and some plaques. The upper 3 cm are intensively crumbled. (1 cm: 10YR 3/4, 4 cm: 7.5Y% 5.8)

A7 71m. Mix of coarse and fine material. Smooth and sintered surface with some plaques and cracks. Enrichment of fine sand in the upper mm. Some bacterial cover under humid conditions.(1cm:10YR 5/6, 2cm: 5YR 3/6, 4 cm: 5YR 3/4).

A8 83,4m. Island of coarse material, slightly updoming, partly in parallel rolls. Crumbly material of middle sand and coarse sand. Consolidated surface with some plaques of apported material. Upper 3 cm slightly rooted. (1cm: 10YR 4/4).

A9 95m. Updoming material of Valea Minului (red, 7.5 YR 5/8). About 2 cm high parallel running swollen rolls, small cracks, salt crystals, crumbly connected, some sufrosion hollows.

A10 100m. Loose material. Bare surfaces with separating plaques. Apparently a repeated formation by dew fall. No rooting. Dust development combined to cracking. (1cm: 10YR 5/3)

A13 110,2m. Coarse material, ms and small and large gravel, some wooden splinters. Bare and smooth surface on a sintered coarse sand -layer and some small gravel. Material from Valea Mare above tailings from Valea Minului. (1 cm: 10YR 6/4, 3 cm: 7.5YR 5/8)

A15 112,7m. Inner slope of the eastern wall, about half of its height. *Festuca* terracettes as an anti- erosion measurement. Fine material as cover of fluvial sediments (rounded gravel) moss cover and leave shedding. Upper cm s slightly crumbled (2cm: 10YR 5/3)

The samples mainly show the phenomena of a mineral organisation and structuring. It contents the formation of clay sealing crusts (A1, A2, A7, A10), which may crack under desiccation (A4, A10). Salt and gypsum crystallisation provoke an updoming or uprolling of the near surface material (A9l. It is obvious that a biological organisation starts very soon too. This includes the bacterial and algae film and pellicular formations (A2, A7) or moss covers with some leave shedding (A13) and especially the formation of crumbs by annelidae or collembolae (A4, A10, A15). This biological structuring starts on places with coarser material and with an elevation above the tailings surface. These organisation and structuring is very similar to those known from semiarid and arid environments around sebkhas (Abichou 2002).

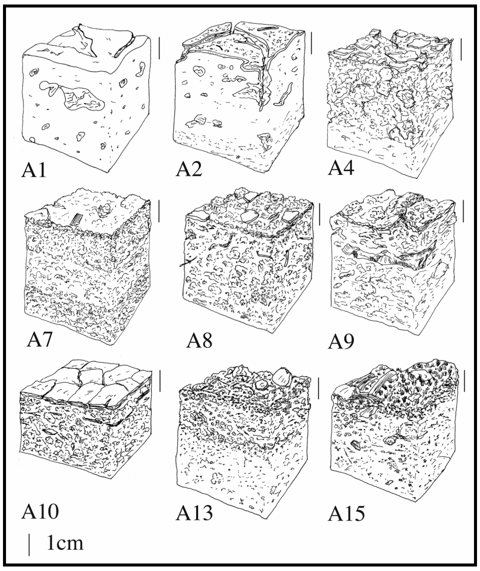

Fig. 3 Surface types and near surface soil structure from the Anies/Rodna tailing pond. Transect A.

2. Developments on covered tailings

Transect G (A 2006) NW part of the ponds surface. From the pool via *Alnus* thicket to the *Hippophae* thickets. The samples were collected in two sections. One from the pool to the first *Hippophae*-stands (G1-G6) and a second about 50 m apart within an open space in the *Hippophae*-thickets (G7-G10). These samples present the part of the pond which got an additional soil cover (s.a.).

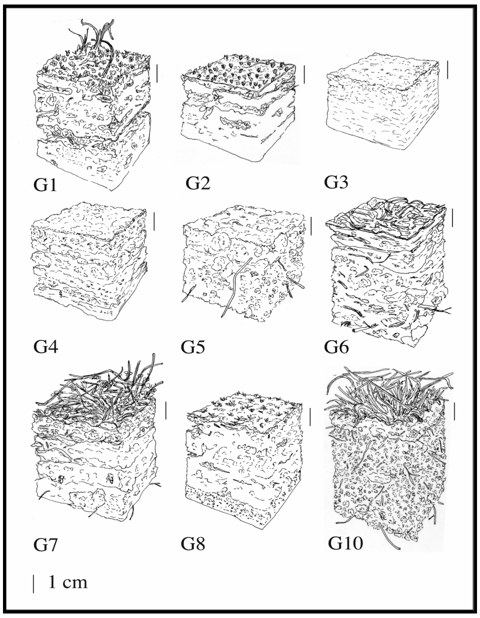

Fig. 4 Surface types and near surface soil structure from the Anies/Rodna tailing pond. Transect G

G1 Mica rich silt in cm thick layers. Sparse moss cover between *Typha* reed. Smooth surface with saltcrystals. O.5 cm deep intensively rooted. Tailings from Valea Minului (1 cm: 5YR 5/8) over material from Valea Mare (6cm: 10YR 5/6)

G2 Sparse moos cover with a hair carpet, algae film. Solid layers of silt, separated by worm hollows. Smooth surface. (2 cm: 7.5 YR 4/6, 5 cm: 10 YR 5/6)

G3 Layered mica-rich silt. Smooth surface. Upper 2 cm with a crumbly structure, (1 cm: 10 YR 6/8).

G4 Mica rich silt with a layered structure. Slightly smooth surface with algae films. Plate structure. No vegetation cover. (1cm: 10 YR 4/6, 4 cm: 7.5 YR 4/6)

G5 Smooth/crumbly surface and a general crumbly structure. Longer roots. Upper crumbs mechanically connected. Outer part of the *Hippophae* bushes with algea films. Red material (1 cm: 5 YR 4/6)

G6 Loose sediment with a plate structure. Intensively rooted. Smooth surface in small plates. *Hippophae* leaves, moss hairs. Beneath a *Hippophae*- thicket. (4 cm: 5 YR 4/6)

G7 Layered silt/ middle sand in separated banks. Some weathered pieces of rock. Apparently part of the secondary soil cover. Intensively rooted and crumbly. Grass felt with singular crumbs. Outer part of a *Hippophae*-thicket with *Trifolium* and algae films. (2 cm: 10YR 5/3, 6 cm 10 YR 5/3).

G8 Layered silt with fine and middle sand. Crumbly structure. Secondary soil cover on tailings from Valea Minului. Smooth surface with a sparse moss cover. Open space between Hippophae–thickets, mosses and algae. (2cm: 10YR 5/4, 6 cm: 5 YR 4/6).

G10 Grass felt. Completely rooted and crumbly sediment. Upper centimetres consolidated. Part of the Secondary soil cover. A_h –Formation. Open space between *Hippophae* thickets, Herb cover with *Trifolium* and *Globularia*. (2 cm: 10 YR 4/4.)

The samples of the G transect depict the interdependency of plant cover and soil formation. A biological structuring starts after the first colonisation with mosses (G2, G8). The efficiency of a grass cover is visible in G7 and G8. Bushes like *Hippophae* also a microclimate and undisturbed situation favourable for annelidae and their crumb formation (G5).

B Soil development on the outer terraces

The third of the outer terrace was the place of previous investigations of the Cluj-Napoca group (See Cristea et al 1995). In exposed the difference densely vegetated slopes and bare terrace surfaces and several tree plantings.

Thus, it allowed a comparison with the bare deposits and the additional soil cover on the pond surface. In addition measurement on one sit of linear soil erosion were done.

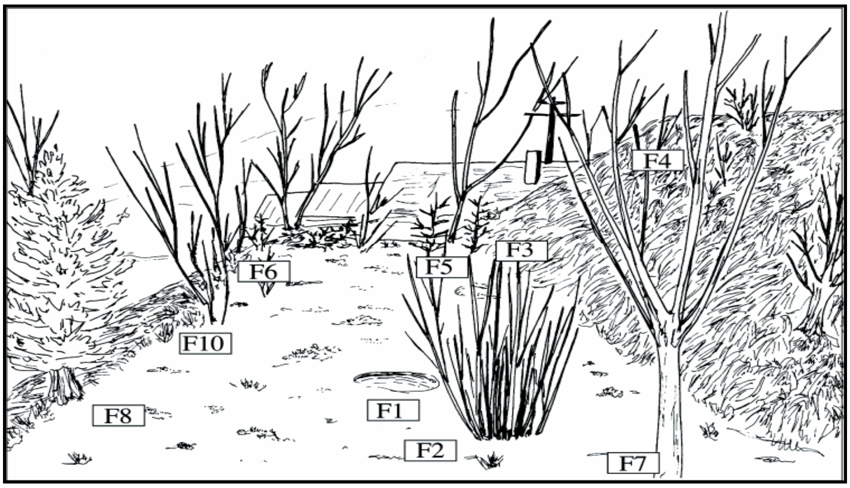

Fig. 5 Northeastern part of the outer terraces of the Anies/Rodna tailing pond with the location of the soil samples. Note the stabilised slopes with a dense grass cover. The terrace surface mainly remains bare. Various trees were planted in 1987 in order to follow their influence of soil activities.

1 Soil development of the surface and slopes of the outer wall terraces.

Transect F. 17.3.07. External part of the ne margin of the third terrace. Experimental plot of the Cluj-Napoca group (cf. Cristea et al. 1995). Whitish-grey material (Valea Mare) and a planting of *Pinus, Salix, Robinia, Alnus, Betula, Hippophae* in small groups. Steep slopes with *Dactylis and Festuca* cover, moss, some *Salix* and *Picea*. The terrace surface remains bare with the exception of some moss groups.

F1 Pit on the middle of the terrace near an experimental pit with remnants of a brown soil cover. Homogeneous fine and middle sand. Bare smooth surface, (1cm: 10YR 6/2)

F2 Pit on the terrace surface west of F1. Compacted fine and middle sand. Slightly rooted. Moss cover, leaf shedding, splinters. (2cm: 10YR 5/3) F3 Slightly terraced steep slope. Remains of the deposition of soil plates and cross wise *Festuca* planting. Mosses and grass cover. Fine sand and silt. A crumbly surface with some splinters. Annelidae droppings. Well rooted. Formation of an Ah visible by large crumbs. (1cm: 10YR 5/2, 4 cm: 10YR 6/4, 6 cm: 10YR 6/1)

F4 Terracette on the middle slope, A 5 cm soil cover with some stones. Grass cover Finely crumbled. Grass felt on large crumbs, well rooted, Ah formation (1cm: 10YR 4/3, 3 cm: 10YR 6/4, 4 cm: 10YR 7/1).

F5 Terrace surface, *Hippophae* thicket about 8o cm high. Some *Festuca*. Bare smooth surface with some mosses and splinters. Fine and middle sand. Slightly crumbled in the upper part, compacted in the lower part. Formation of a thin Ah horizon. (1cm: 10YR 7/3, 2cm: 10YR 6/3)

F6 Margin of the terrace. Grass, mosses beneath some *Salix*-bushes. Compacted fine and middle sand, in the upper part more solid. Slightly crumbled with many roots. OL/Of, grass felt, splinter. A very thin Ah. (0,5 cm: 10YR 8/3 Ah, 2,5 cm: 10YR 6/ 3)

F7 Inner part of the terrace. Homogeneous fine and middle sand. Crumbled surface, with an initial moss cover. A 1,5 cm thin Ah,. Some insect larvae, (1cm: 10YR 6/3)

F8 Beneath a *Picea* tree*,* Fine and middle sand. Finely rooted, Of, crumbled surface, with splinters. 1 cm Ah formation (1cm: 10YR 4/4, 3 cm: 10YR 5/4 3 cm).

F10 Terrace surface beneath a *Robinia*, Dense homogeneous fine and middle sand. Leaf shedding. Ol/Of. Formation of a thin Ah by crumbling, (1cm: 10YR 3/4, 3 cm: 10YR 5/4)

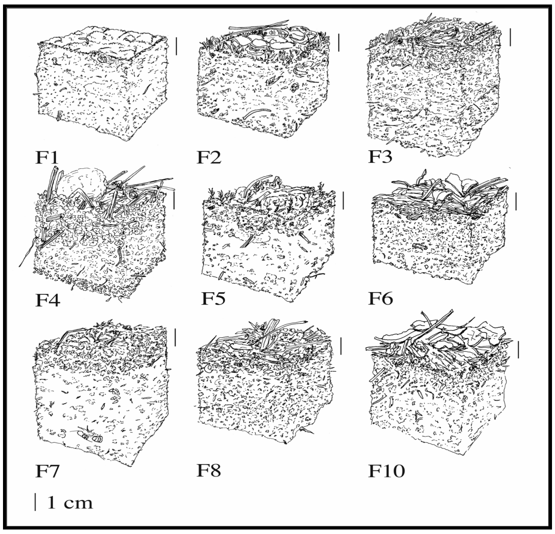

Fig. 6 Soil surfaces and near surface structures of samples taken on the outer terraces of the Anies/Rodna tailing pond. For location see figs. 3 and 6.

These soil samples depict the biologic structuring phenomena. Even on samples with a bare surface the rooting proofs the influence of the near vegetation. The grass cover of the slopes is densely developed and resistant against trampling. The soil development is advanced to the formation of A_h horizons (F3-F10) and reached already the status of a ranker soil type. For a certain part it will be due to the secondary cover with soil material in 1987 (cf. Cristea et al.1995). However, it is clear from these observations that this site follows the dynamic of forest soil formation (cf. Schulz et al. 2005)

Fig. 7. Stable terraced slope covered by vegetation

Fig. 8 Slope affected by linear erosion

2. The problem of linear soil erosion on the slopes.

Even the grass cover of the lower terrace slopes is a effective protection against soil erosion, it still is prone to these phenomena, when the grass cover will be opened, such as by digging for building material. One of these diggings was investigated in 2007 on the external slope of the eastern wall (see SR on fig. 3).

From geomorphological point of view the deposit is relatively stabile. The fragility of the components which consists the system could cause, in case of human pressure (digging for construction materials) or in case of natural pressure (heavy rainfalls, thick snowlayer, overmoisturing a.s.o), the activation of some linear and areal erosional processes woth severe consequences over the environment.

Conclusions

First results show the prevailing mineral organisations to pellicular surfaces and sufrosion phenomena near the pond. However the clay and bacterial sealing is a rapid and general phenomenon. The two tailings act differently. The red and sulphur rich material from Valea Minului shows the typical surface development known from sebkhas with gypsum rich sediments. These are doming or crystallisation mostly destroying the pellicular surfaces.

On places where plant colonisation took place, the biological structuring by collembolae and/or annelidae is visible. It already starts with a moss cover, which provokes a crumbly structure of the upper soil material. A sparse grass vegetation may lead to grass felts also inducing the crumbly structure by annelidae. However it is not in general that a shrub or tree cover already leads to thicker upper horizons. Sand on the upper walls f.ex. only shows very thin soil development.

The samples in the northwestern part of the pond were taken beneath the denser shrub and tree layers. They clearly show a development of an Ah horizon in various developments. However, this also is the area where alluvial soil material was spread in an about 5 cm thick cover.

The samples from the about 10 years old tree planting on the lower terraces expose well-developed Ah horizons too. Especially under a grass cover, these horizons could develop.

Aknowlegdement

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