GRANULOMETRIC AND MORPHOMETRIC CHARACTERISTICS OF RUDITIC AND ARENACEOUS CLASTS FROM RED QUATERNARY DEPOSITS (CETATE AREA, DOLJ COUNTY, ROMANIA)

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Abstract. The sampling area is located near the Dolj and Mehedinţi County border, about 10 km north of the Danube. The Quaternary red deposits from Oltenia (SW of Romania) comprise loess, loess like deposits and gravels with red silty sand matrix. This paper presents data concerning morphometry and granulometry of ruditic clasts by rock type and data about the granulometry of subarenitic fraction, with a short description of the petrography of sands.

Keywords: Quaternary, loess like deposits, morphometry, granulometry, rudite, arenite.

Rezumat. Caractere morfometrice şi granulometrice pentru clastele ruditice şi arenitice din depozitele cuaternare roșii (zona Cetate, județul Dolj, România). Zona din care au fost culese probele pentru analize se găseşte în apropierea limitei dintre judeţele Dolj și Mehedinți la aproximaiv 10 km nord de Dunăre. Depozitele cuaternare, de culoare roșie din Oltenia (SV României), cuprind depozite loessoide, loess-uri și pietrișuri cu matrice arenito-siltica. Lucrarea de faţă redă date referitoare la caracterele morfometrice şi granulometrice clastelor ruditice, luând în considerare petrografia acestora şi granulometria fracţiei arenitice şi subarenitice, cu câteva detalii referitoare la petrografia nisipurilor.

Cuvinte cheie: Cuaternar, depozite loessoide, morfometrie, granulometrie, rudite, arenite.

INTRODUCTION

Starting from about 5.5 kilometres NW of Cetate settlement, on a sector approximately 4 kilometres long, directed towards Obârşia de Câmp, there are to be noticed several quarries in which Pleistocene sand and gravel from the upper terrace are exploited. According to the hydrogeological map, scale 1:100,000, sheet 40d Cujmir, they are covered by loess-like deposits. Measured vertically, the walls of the deepest quarry display values between 25 and 30 meters. The largest part of the lithological succession is represented by alternating layers of sand and grey gravel. At certain levels, the sands display oblique stratification and, in isolate cases, sand cementing appears, which leads to the formation of 0.3 to 1 meters thick sandstone plates. At the upper part, on the first 1.5 – 2 meters, there are to be noticed the soil horizons that are marked with "g" on Figure 1. Under them, there are located powdery-sandy deposits that contributed to soil formation ("f"). Their thickness varies between 1 and 2.5 meters, sometimes even 3 meters. The cause of this thickness variation is represented by the erosion surface, which pushed the soil horizons downwards, to the detriment of the silty deposit.

The "e" level mainly consists of very fine and coarse gravels, the very coarse gravels accounting for the lowest participation value. The red matrix of these gravels is made of sand and silt, with very low clay participation. The "d" level, characterised by 1.5 – 2 meters thickness, consists of thin alternating layers of sand and coarse gravel, with discontinuous red stripes. The "c"-type levels are made of very well separated, coarse gray sands, while the "b"-type levels consist of coarse and very coarse gravels, mixed with gray sands. The "a" level is made of medium and fine yellow-gray sand.

The samples were collected from the "e" level (Cetate 1 p.), from the base and from the middle segment of the "f" level (Cetate 1 s.). Elements of gneiss, gabbros and andesites were identified in the gravel and white boulder situated at different depths as compared to the red deposits from this point.

MATERIALS AND METHODS

The researched literature indicates that, in order to obtain data related to gravel morphometry it is necessary to place the clast with its maximum projection surface (ab plan) on a sheet of paper, to trace its outline and then to measure the radiuses of the corners by using a template of concentric circles drawn on a transparent film (DOBKINS & FOLK 1970).

Another method implies the delineation of the contour of the clast placed on a glass surface located above a light source situated in the focal point of a concave mirror (DUMITRIU et al, 2011).

The values of the radiuses, obtained by using the template of circles on the contour delineated by applying Dumitriu's method, were introduced in Excel files. In order to represent the position of the clasts in the Sneed & Folk shape diagram, of the values corresponding to the Maximum Projection Sphericity (MPS, Ψ_P) and of the Oblate – Prolate Index (OPI), there was used the Excel worksheet realised for this type of operations (GRAHAM & MIDGLEY, 2000). The granulometric measurements on the upper fine deposits and on the red matrix of the gravel were conducted in the Sedimentology Laboratory of the University of Bucharest, by using a Partica LA-950 analyzer (Horiba). This device can measure samples in liquid suspension within a granulometric interval of 0.01 μm – 3 mm. In order to obtain a more accurate result, the measurements conducted through this method require that the analysed sample be brought to a state of uniform suspension, following the removal of the organic matter, of the carbonates or of other substances that lead to the formation of mineral aggregates.

The procedure conducted for sample preparation, up to the application of the disperser (inclusively), is the same as the one used in the X-ray diffraction analysis.

RESULTS AND DISCUSSIONS

Gravels

As it can be noticed in Table 1, of the entire volume of the gravels in the "e" level, the very fine ones represent the highest part; together with the fine and medium gravel, they account for about 70 percent of the total ruditic clasts.

Table 1. Volume percent values for the granulometric classes of gravel, Cetate sampling point

Diameters	32-64 mm	16-32 mm	8-16 mm	4-8 mm	2-4 mm
Percent	11.43	22.09	15.89	14.44	36.12

The morphometric characteristics are presented only for the clasts that display a diameter higher than 16 mm.

The morphology of the clasts takes into consideration all the surface characteristics that are present in the case of a sedimentary particle. The processes undergone by a clast (physical-chemical alteration under the influence of environmental factors, erosion, and transportation type) leave their mark on them under the form of fractures, abrasion surfaces and characteristic surface textures (BENN & BALLANTYNE, 1993).

By studying these properties, together with the petrographic and the granulometric analyses, important information can be obtained on the source area of the sediments, on the transportation environment and on the sedimentation processes (KRUMBEIN, 1941; PETTIJOHN, 1949).

The expression "particle (clast) morphology" comprises four main concepts (FOLK, 1980), which are presented here in the descending sequence of their importance:

- shape
- contour (roundness, angularity)
- sphericity
- characteristics of the clast surface. In order to establish their value, several parameters are to be measured; subsequently, only those parameters used in the present study will be briefly presented.

Shape is defined as the property that addresses the relation among the maximum, the minimum and the medium diameters of a clast (FOLK, 1980). By considering the c/a ratio and the (a-b)/(a-c) ratio, both displaying values between 0 and 1, the Sneed & Folk ternary diagram for shape (Figure 2) separates 10 classes:

1. C-compact, 2. P-platy, 3. B-bladed, 4. E-elongated, 5. CP-compact-platy, 6. CB-compact-bladed, 7. CE-compact elongated, 8. VP-very platy, 9. VB-very bladed and 10. VE-very elongated.

Following the examination with the mineralogy magnifying glass and based on the observed features, the quartzite can be divided into several categories that influence the shape.

Thus, in the case of certain quartzites, there can be seen quartz crystals with sutural contacts, being probably formed through the metamorphosis of sedimentary rocks. These are usually projected in the lamellar shape field.

In the same field, there are also situated quartzites that display lens like areas (similar to feldspars porphyroclasts in augen gneisses), indicating the deformation caused by a tectonic action; they could originate in gneiss or mica-schists.

The white, transparent, gray quartzites, or those consisting of white, gray or transparent areas, which pass from one to another gradually, without a clear limit, can be meta-quartzites or they could even be, in fact, quartz deposed in cracks (vein quartz) or derived from the weathering of granites with pegmatitic or porphyric structure.

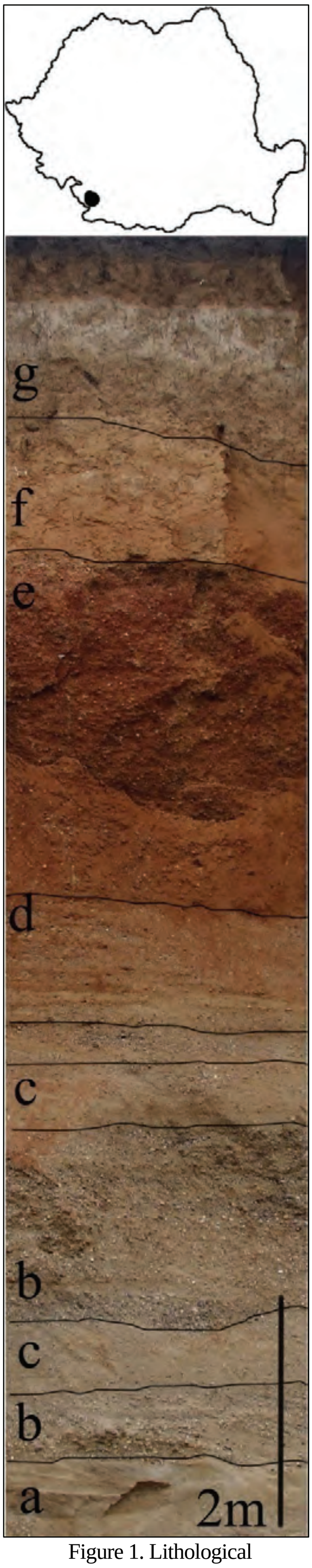

Figure 1. Lithological succession in the sand and gravel quarries within the Cetate area and approximate location of the sampling site in Romania; explanation of the notes in text.

Table 2. Proportion of shape classes for gravel, according to petrography, Cetate sampling point.

rock	Shape classes, after Sneed and Folk									
	C	CP	CB	CE	P	B	E	VP	VB	VE
quartzite	0.8	3.2	8	5	14.3	27.8	15.9	5.6	16.7	3.2
sandstone	0	6.7	0	0	0	33.3	20	13.3	26.7	0
silicolite	8.3	0	8.3	0	8.3	8.3	25	0	33.3	8.3

These are often projected in the fields of the compact shape.

The influence of petrography on shape is easily seen on sandstone, where, unlike in the case of quartzite, there are present important parts of the clasts with very bladed and/or elongated shapes. The bladed, elongated and very elongated shapes are the most common in the case of sandstone.

In the case of the silicolite found at Cetate, the highest proportion is accounted for by clasts with very bladed shape. As compared with other sampling points, at Cetate, the platy and the very bladed clasts account for the highest proportion.

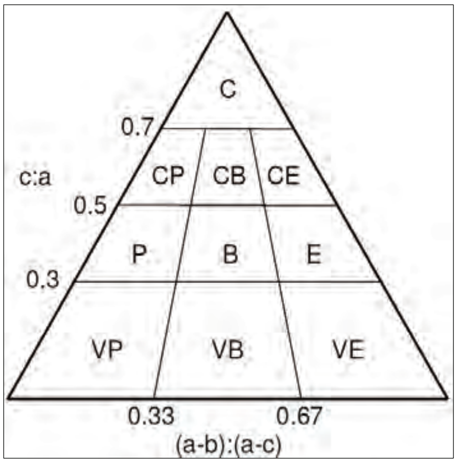

Figure 2. The Sneed & Folk ternary diagram for clast shape (GRAHAM & MIDGLEY, 2000)

OPI

In order to establish if the intermediary axis (b) is closer, in value, to the maximum (a) or to the minimum (c) one, there was introduced a new index, marked OPI - oblate prolate index (Dobkins & Folk, 1970), which supplies more information on the shape of the particles

The following formula was used in order to compute OPI:

$$OPI=10[(a-b)/(a-c)-0.5] :(c/a), \text{ equation (1)}$$

By replacing the letters that symbolise the three axes with values corresponding to the clasts characterised by perfect blade ratio (i.e. the intermediary axis is placed, in value, at equal distance from the maximum and from the minimum axes, b=c+(a-b)/2), the 0 value is obtained for OPI (PYÖKÄRI, 1980).

The more accentuated the discoidal (i.e. oblate) character of the clasts, the lower will be the OPI negative values; when the clasts are closer to the elongated cylindrical shape (i.e. prolate), the OPI values will be positive and increasing (DOBKINS & FOLK 1970).

The analysis of Figure 3 and Table 3 shows the concentration of the OPI values in the interval comprised between the isolines -5 and 5 (55%) in the case of quartzite, while in the case of sandstone, only three clasts are excepted from the same interval.

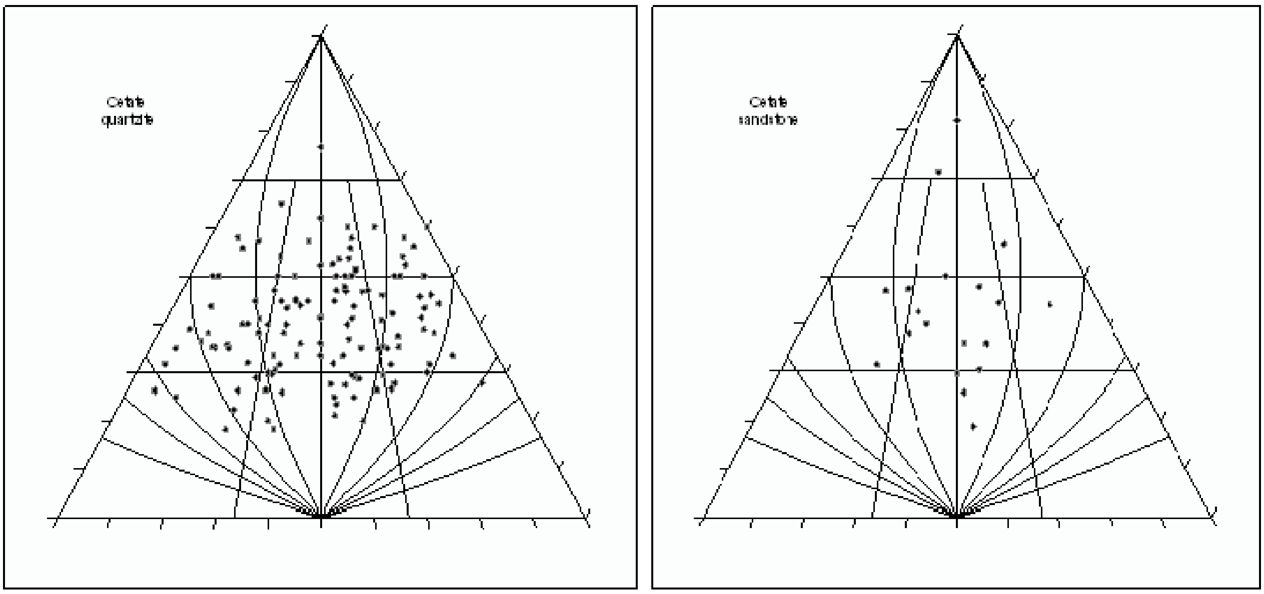

Figure 3. Projections of the results of the measurements in the shape and OPI values fields: quartzite (left) and sandstone (right), in the upper gravels from Cetate.

Table 3. Proportions of the OPI values, on rock type, in the case of the >16 mm gravel, Cetate area.

rock type \ classes	-20	-15	-10	-5	0	5	10	15	20
quartzite	0.8	4	16	20.8	0	34.4	22.4	0.8	0.8
sandstone	4.7	0	23.8	23.8	0	23.8	14.3	9.5	0
silicolite	0	0	25	0	0	41.66	33.33	0	0

The contour (roundness, angularity) of the clast renders, by means of measured values or through visual estimation, the extent to which the respective clast is characterised by sharp or rounded corners.

The chosen method for rendering the roundness of the particles measured in the present paper is that introduced by WADDELL in 1932, i.e. the Waddell roundness, marked R_W. The values corresponding the Waddell roundness (R_W) are obtained by dividing the sum of the radiuses of the circles that can be inscribed into the corners (r), to the result of the multiplication between the total number of the corners (N) and the radius of the biggest circle that can be inscribed to the measured clast (equation 2).

At Cetate, the silicolite characterised by sub-rounded and rounded contour display R_W values almost entirely comprised in the 0.35 - 0.6 interval, while in the case of sandstone, the value concentration interval is 0.4-0.8, and that characteristic to quartzite is 0.4 - 0.7. Using the roundness classes associated to different Rw values by Krumbein, we have established that most of the clasts are characterised by rounded and sub-rounded contour (Table 4).

$$R_W = \frac{\sum r}{NR}$$, equation (2)

Table 4. Proportions of Wadell roundness classes, on rock type, Cetate sampling point.

rock	very angular	angular	sub-angular	sub-rounded	rounded	well-rounded
quartzite	0	0	8.06	33.06	47.58	11.29
sandstone	0	0	5.88	11.76	41.17	41.17
silicolite	0	0	10	40	50	0

The sphericity of a particle refers to the degree to which the shape of that particle is similar to a sphere; in other words, it expresses the closeness in value of the three diameters a, b, c (FOLK, 1980).

Marked Ψ_P, the **maximum projection sphericity** is defined as the ratio between the maximum projection area of a sphere that is equal in volume with the particle under study and the maximum projection area of the particle itself (SNEED & FOLK, 1958).

Another notation for Ψ_P is MPS, the abbreviated form for Maximum Projection Sphericity.

The computation formula for Ψ_P is:

$$\Psi_P = \sqrt[3]{\frac{c^2}{ab}}$$, equation (3)

At Cetate, Ψ_P displays values comprised between 0.35 and 0.87, most of them being concentrated in the 0.5-0.7 interval. The Ψ_P values for sandstone are concentrated in the 0.4-0.75 interval and for quartzite in the 0.4-0.8 interval, while the silicolite sampled at Cetate display Ψ_P values between 0.4 and 0.9, their concentration interval being 0.4-0.6.

DOBKINS & FOLK (1970), show that in the case of the basalt gravel, as well as in that of the quartz gravel, the 0.66 MPS value separates the littoral environment from the fluvial one. By projecting the MPS and OPI values on the same graph, the aforementioned authors separate the fluvial depositional environment from the littoral one. Widera 2010, quoting STRATEN (1974) and GALE (1990), also includes in the category of gravels deposed in littoral environment those that display MPS values comprised between 0.64 and 0.53, irrespective of their OPI value.

By applying the DOBKINS & FOLK method for the Cetate sampled quartzites, it can be noticed (Figure 4) the almost equal distribution of the clasts theoretically formed in the fluvial environment (40) and in the littoral environment (46). If the observations of Straten and Gale are also taken into consideration, another 23 clasts can be regarded as being formed in the littoral environment, reaching, thus, a total of 69 clasts.

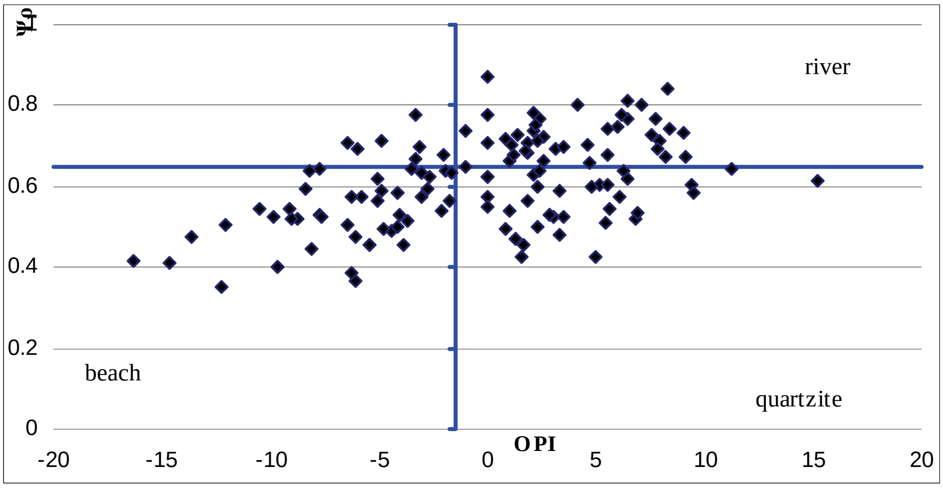

Figure 4. Quartzite clasts, projected by taking into consideration MPS (vertical) and OPI (horizontal). In blue: the MPS value of 0.65 (horizontal) and the OPI value of -1.5 (vertical)

Gravel petrography

Among the magmatic rocks, only one altered andesite clast was identified in all the ruditic clasts analysed; the dimensions of the a/b/c axes were 22/20/15.

The metamorphic rocks through quartzite represent the main rock type encountered. The quartzites account for a participation of more than 75 percent in the total gravel volume.

There was also identified a gneiss clast, but, as in the case of the andesite, it was much altered.

The sedimentary rocks hold a participation of about 23 percent in the total number of clasts; more precisely, the sandstone and the micro-conglomerates represent 13.77 percent, while the silicolite account for 8.98 percent.

Clasts identified as sedimentary rocks:

- quartzitic sandstone (31/28/18); -gray-green sandstone (21/14/9); -quartzitic sandstone (28/12/11); -dark quartzitic sandstone, the quartz(ite) clasts display smoky-gray colour (20/16/6); yellow quartzitic sandstone with transparent quartz clasts (27/20/3); white quartzitic sandstone (20/10/9); gray sandstone made of coarse sand ~10 percent, the rest being represented by medium sand, (18/10/4); -gray-blackish fine sandstone (21/14/3); medium to fine gray quartzitic sandstone (20/10/7); fine sandstone with white veins (20/13/3); medium gray quartzitic sandstone (20/15/5); yellow fine sandstone (17/13/5); medium yellowy sandstone (27/19/7); medium-coarse light-grey sandstone (21/13/4).

-micro-conglomerate with arenaceous yellow-reddish matrix and quartzite lithoclasts of 3 – 8 mm (25/15/3); micro-conglomerate with quartzite lithoclasts of 3 – 8 mm (~25 percent) and arenaceous matrix made up of arenite with a fine black matter, the latter representing about 40 percent of the total (25/18/8); micro-conglomerate with very coarse sandstone matrix and elements of very fine gravel (~5 percent), (22/15/12).

-reddish silicolite (liver colour) (25/20/15); reddish silicolite with fine veins (24/17/5); -yellow silicolite (28/13/6); finely veined, reddish silicolite (19/16/8); brown silicolite with circular formations, 20 mm (20/14/8); reddish silicolite (23/11/7); yellow-brown silicolite (19/14/5); veined silicolite (22/14/7).

In all presented cases of silicolite, there are to be noticed fine circular or slightly ellipsoidal particles that resemble fine, rounded sand. The highest proportion accounted for by such formations, observed with the mineralogical magnifying glass (16x), was around 10 - 15 percent.

The circular formations within the thin sections observed at microscope proved to be tests of radiolarians.

Upper fine deposits and the red matrix of the sand

There was followed the proportion of the granulometric intervals corresponding to the lutites (<4µm), the very fine (4-8 µm), fine (8-16 µm), medium (16-32 µm) and coarse (32-64) silt, the very fine (63-125 µm), fine (125-250 µm), medium (250-500 µm), coarse and very coarse (500 µm-2 mm) sand.

The granulometry measurements resulted, in average, in the values presented in Table 5.

By projecting these values in the Shepard granulometric diagram (Shepard 1954), which graphs the proportions of sand, clay and silt, these upper red deposits can be identified as sandy silts and the matrix of the gravels can be identified as silty sands.

In order to establish the mineralogical composition of the upper fine deposits, there were realised thin sections on samples taken from these deposits.

Because of the friability of the rock, the sections could not be grind up to the optimal thickness for a microscope analysis.

Nevertheless, on several sections, it was possible to identify the dominant presence of the quartz and, secondarily, of the feldspar and the muscovite. The very high proportion of the quartz can be observed on the microscope photos presented in Fig. 6.

Table 5. Percentage of loess deposits and of the matrix of the associated ruditic deposits, within the lutite – coarse sand interval (for the projection of the values on Shepard's diagram, see Figure 6.1)

granulometry / sampling point	lutite	very fine silt	fine silt	medium silt	coarse silt	very fine sand	fine sand	medium sand	coarse sand
3 Cetate p matrix	2.93	10.80	14.86	5.24	2.94	5.41	5.48	18.60	33.72
4 Cetate s. loess	8.25	12.38	17.14	9.35	7.17	14.67	15.21	3.60	12.24

At Cetate sampling point, around the clasts in the upper fine deposits, there are to be noticed calcite outer covers, this representing a characteristic of the loess deposits (SMALLEY et al., 2011). However, the granulometry of these deposits is different from what the same author considers to be characteristic of loess. Thus, the main granulometric fraction in the typical loess should be the fine, medium and coarse silt (10 to 50 microns in diameter), accounting for a participation of 40-70 percent. At Cetate, this granulometric interval has a participation of about 30 percent and the sand surpasses the maximum limit of 25 percent, its presence accounting for more than 45 percent (Fig. 5).

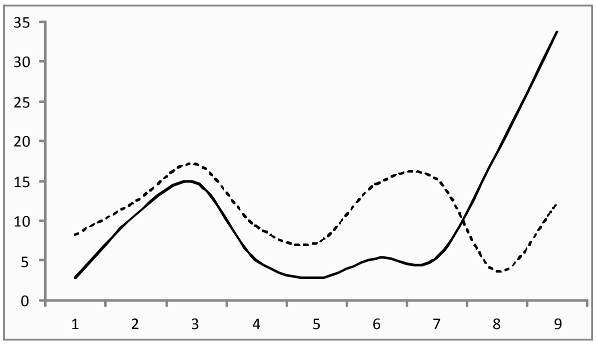

Figure 5. Sand, silt and clay percent in gravel matrix-continuous line and in fine red upper deposits-dashed line. 1. clay; 2. vf silt; 3. f silt; 4. m silt; 5. c silt; 6. vf sand ; 7. f. sand; 8. m. sand; 9. c. sand (f-fine, m-medium, c-coarse, vf-very fine)

In connection to the mineralogy, there is also to be mentioned the presence of certain black particles, with dimensions characteristic to the medium to fine sand, which are present both in the red gravel matrix, as well as in the loess deposits. The black colour could originate in the organic matter or in the manganese oxides and hydroxides, which cover the arenaceous clasts.

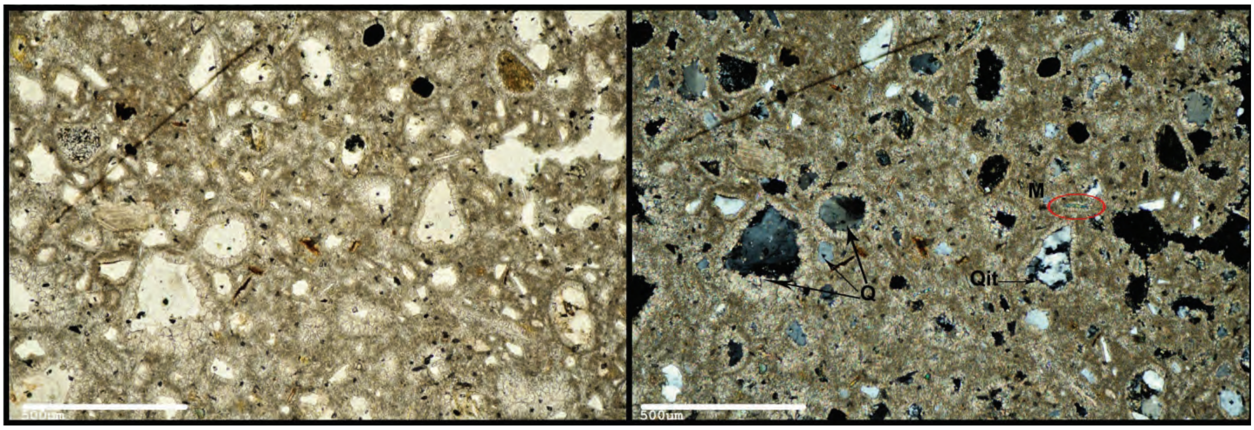

Figure 6. Thin sections in the upper fine deposits from Cetate. Around the particles, there are to be noticed calcite outer covers. Left with parallel nicols, right with crossed nicols; Q-quartz, Qit-quartzite lithoclast, M-muscovite.

CONCLUSIONS

From the petrographic viewpoint, the level of gravels generally included by their diameters in the very fine to medium classes, which is located at Cetate, immediately under the red sandy silt level, is mainly composed of quartzites (more than 75 percent); the next petrographic category is represented by sedimentary rocks, which account for approximately 23 percent. The identified sedimentary rocks were sandstone, micro-conglomerates and silicolite (radiolarite).

The quartzites mainly display B shape, but there also appear in approximately equal proportions quartzites of P and E forms. The OPI values for quartzites that are comprised between 5 and -5 account for 55 percent. At Cetate, the sandstone is characterised by Ψ_P values that are concentrated in the 0.4 - 0.75 interval, while the values for the quartzites range between 0.4 and 0.8 and the silicolite display Ψ_P values between 0.4 and 0.9, the interval of concentration being 0.4 - 0.6.

The projection of the Ψ_P and OPI values on the same graph reveals the predominance of the gravels from the littoral domain, 69, as compared to those from the fluvial domain, 40. This is possible following the remoulding of certain initially littoral deposits that were subsequently mingled with fluvial deposits.

The upper sandy silts, located above the gravels, are composed of quartzite lithoclasts, fragments of quartz, feldspar, calcite and, possibly, garnet. Calcite outer covers are formed around the sandy and silty particles. Although this feature is also met in the case of loess, it is not enough to characterize them as such, because of the almost double proportion of sand as compared to the maximum noticed in loess. This last feature justifies the use of the term *loess-like* in the characterization of these deposits.

REFERENCES

BARNHISEL R. I. & BERTSCH P. M. 1989. *Chlorites and hydroxy-interlayered vermiculite and smectite*. In J. B. Dixon & S. B. Weed (Eds.) Minerals in soil environments. 2nd ed. SSSA, Madison. Wisconsin: 729-788.

BENN D. I. & BALLANTYNE C. K. 1993. *The description and representation of particle shape*. Earth Surface Processes and Landforms. **18**: 665-672.

CARVER R. E. 1971. *Procedures in sedimentary petrology*. Wiley Interscience. New York. 653 pp.

DOBKINS J. E., FOLK R. L. 1970. Shape development on Tahiti-Nui. *Journal of Sedimentary Petrology*. **40**: 1167-1203.

DUMITRIU D., NICULITA M., CONDORACHI D. 2011. Downstream Variation in the Pebble Morphometry of the Trotuş River, Eastern Carpathians (Romania). *Forum geografic. Studii şi cercetări de geografie şi protecţia mediului*. **10**(1): 78-90.

FOLK R. L., 1980. *Petrology of sedimentary rocks.* Hemphill Publishing Company. Austin. Texas: 183 pp.

GRAHAM D. J. & MIDGLEY N. G. 2000. Graphical representation of particle shape using triangular diagrams: an Excel spreadsheet method. *Earth Surface Processes and Landforms*. **25**(13): 1473-1477.

GHENEA C. & GHENEA ANA. 1981. *România. Harta hidrogeologică scara 1:100 000, foaia 40d Cujmir*. Institutul de Geologie şi Geofizică. Bucureşti.

KRUMBEIN W. C. 1941. The effects of abrasion on the size, shape, and roundness of rock fragments. *Journal of Geology*: 482–520.

MAURI PYÖKÄRI. 1980. Shape development of trondhjemite pebbles and cobbles on shores in the southwestern Finnish Archipelago. *Géographie physique et Quaternaire*. **34**(3): 335-350.

PETTIJOHN F. J. 1949. *Sedimentary rocks*. Harper & Brothers. New York: 526 pp.

SHEPARD F. P. 1954. Nomenclature based on sand silt clay ratios. *Journal of Sedimentary Petrology*. **24**:151-158.

SMALLEY I. J., MARKOVIC S. B., SVIRCEV Z. 2011. Loess is [almost totally formed by] the accumulation of dust. *Quaternary International*. **240**: 4-11.

SNEED E.D., FOLK, R.L., 1958. Pebbles in the lower Colorado River, Texas, study in particle morfogenesis. *Journal of Geology*. **66**(2): 114-150.

WADDELL H. 1932. Volume, shape, roundness of rock particles. *Journal of Geology*. **40**: 443-451.

WIDERA M. 2010 The morphology of fossil pebbles as a tool for determining their transport processes (Kozmin South, lignite open cast pit, Central Poland). *Annales Societatis Geologorum Poloniae*. **80**: 315–325.

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