PHYTOLITHS AND ARCHAEOLOGY: A CASE STUDY FROM THE STARČEVO SITE OF DUDEŞTII VECHI, ROMANIA

Iosif Moravetz

The identification and interpretation of phytoliths recovered from archaeological soil samples have been gaining acceptance in archaeology in the last several decades. Phytoliths are microscopic minerals consisting of silica bodies deposited in the stems, leaves, roots, and inflorescences of plants whose shapes can be identified to specific plants (Mulholland and Rapp 1992:1). Their potential applicability to issues of prehistoric agriculture and agricultural technology, wild and domesticated plant use, and the reconstruction of paleoenvironments has strengthened the position of phytolith research as a viable method for archaeologists. As part of phytolith research it is important that archaeologists become familiar with the history of phytolith studies, the natural occurrences and systematics of phytoliths, their recovery from soil sediments, and their role in different interpretive schemes. The aim of this paper is to provide a brief outline of phytolith research and introduce a case study where phytoliths recovered from soil sediments at the Neolithic site of Dudeştii Vechi, Romania, are discussed within an economic and environmental context.

Phytolith Studies

Calcium phytoliths have been known to exist as early as 1675, when Loeuwenhoek first observed them under the microscope (Arnott 1976:57). However, it was not until 1836, when Ehrenberg set out to systematically describe, although he misidentified, silica phytoliths as micro-organisms that reside in plants (Baker 1960). More detailed studies on phytolith formal variation and their relation to plant anatomy did not start until the turn of the 20th Century. Interest in phytoliths steadily increased and soil scientists began to apply plant silica studies to paleoenvironmental reconstruction and paleosol identification and dating (Mulholland and Rapp 1992:5). By 1900 plant silica research extended to the field of archaeology when wheat and barley phytoliths were reported at several European archaeological sites (Netolitzky 1900). Other studies identified wheat and barley phytoliths in the clay used to make pottery (Schellenberg 1908).

From an early beginning studies in Europe aimed at identifying and classifying phytoliths. Christian Ehrenberg, an early pioneer of phytolith classification is considered by some to be the father of phytolith studies (Powers 1992:18). Involved in research throughout northern Europe and central Russia, Ehrenberg produced numerous publications illustrating a variety of phytolith forms and laying the foundation for their biological correlates. German scholars, Grunt and Grob, also expanded upon botanical investigations, correlating phytolith shapes to plants and expanding the knowledge of the long and short cells in the epidermal layers of a wide variety of grasses (Powers 1992:19). Their work has been invaluable to the development of phytolith studies and became the foundation of the German school of phytolith research that included such members as Formanek (1899), Neubauer (1905), Mobius (1908a, 1908b), Netlitzky (1914, 1929), Frohnmeyer (1914), and Frey-Wyssling (1930). In Western Europe, in the 1950's and 1960's the Welsh conducted a study of the three dimensional characteristics of silicified cells in grasses. Hubbard (1968) and Metcalfe (1960, 1971) published significant syntheses of the relationship between phytolith morphology and monocotyledons.

In the New World, the study of phyoliths in archaeology has been a relatively new addition where the objective became the identification of cultivated plants. One of the earliest uses of phytoliths data recovered from an archaeological site was to identify the crops at Kotosh, Peru (Matsutani 1972). Subsequent research concentrated on methods of identifying the earliest occurrence of domesticated maize (*Zea mays* L.). This included the cross-shaped size techniques used to distinguish between irrigated and non-irrigated plants in attempts to infer domestication (Miller 1980; Rosen 1987). Phytolith studies during the 1960's and 1970's dealt with the reconstruction of past environments documenting changes in ecotone boundaries and relative humidity (Pearsall 2000: 398; Carbone 1977; Lewis 1976, 1980). Phytoliths recovered from lake sediments in Mexico, Belize, the Brazilian coast, Puerto Rico and Andean Ecuador contributed to both paleoenvironmental reconstructions and early tropical agriculture (Pearsall 1976, 1977, 1985a, 1985b, 1992, 1994; Piperno 1979, 1980, 1981, 1983, 1985, 1989, 1995).

Phytolith development, morphology and systematics

Plant phytoliths are created in both specialized silica-accumulating cells called idioblasts, and in the cellular and intercellular spaces of plants (Pearsall 2000:359). Their creation begins with the absorption of monosilicic acid, $Si(OH)_4$, from the soil through the root system and upwards into the aerial system where they form solid silica (Pipeno 1988:12). The amount of monosilicic acid present in the soil is dependent on moisture content, temperature, pH value, dissolution of decayed phytoliths, the extent of organic material present, and the presence of aluminum oxides (Piperno 1988:15). Studies have explored the accumulation and deposition of silica in different species of plants and their relationship to soil conditions (Bennett 1980, 1982a, 1982b; Blackman 1968; Dore 1960). Such studies extend to different plant orders, such as the pteridophytes (ferns and related plants), gymnosperms (plants like pine, spruce, fir), monocotyledons (e.g. grass family) and dicotyledons (e.g. manioc and gourds). Archaeological issues on the origins of agriculture have compelled researchers to explore in greater detail many families of plants within the monocotyledon and dicotyledon orders. Metcalfe (1960, 1971) and Metcalfe and Chalk (1973) have researched these orders and have provided a detailed study relating the distribution and morphology of phytoliths belonging to different plant genera.

The morphology of phytoliths created in idioblasts does not necessarily conform to the shape of the plant's parent cell, making the association between plants and phytoliths variable. Consequently, morphological variations due to different phytolith creation processes can be observed in a single plant species. Grasses have been the most intensely studied group of monocotyledon plants because they have the greatest abundance of phytoliths and they hold primacy in discussions of early agriculture. Based on their morphology, grass silica bodies have been grouped into two classes, the long cells and the short cells (Pearsall 2000:361). The long cells are usually sinuous with rectangular, interlocking borders. Their identification is problematic unless other distinguishing features such as spines, hairs or epidermal projections are present. The short cell phytoliths occur in various parts of the plant and are divided into the festicoid, chloridoid, and panicoid classes, each characterized by a specific morphology. Utilizing both long and short-celled silica bodies considerably improves the identification of grasses. A more recent method adding to the identification process is the three-dimensional morphological observations of phytoliths mounted in a fluid medium on a microscope slide. This method allows for a greater degree of accuracy in identifying grasses with morphologically similar short cell silica bodies.

In addition to morphological differences, considerable variation can also be observed in surface ornamentation. Piperno (1988) has noted intricate details on phytolith surfaces and has categorized surface ornamentation into ten separate classes. These include surfaces that are spinulose, nodular, rugulose, smooth, irregularly angled or folded, verrucose, tuberculate, stippled, armed and nonarmed (Piperno 1988:58-60). The intricate surface details observed at magnifications of 400x and 1000x play a significant role in phytolith identification.

A pressing issue in phytolith studies relates to systematics, or the classification of variation in shape and distribution of short and long cells phytoliths (Mullholand and Rapp 1992:1). Terminology and systems of classification are contentious issues to analysts, and to this day they still remain largely unstandardized and subject to the whims of individuals.

Generally, the classification of phytoliths follows two approaches (Mulholland and Rapp 1992). First, the biological approach is usually employed when complete plant tissue fragments can be identified. A major tenet of this approach is the incorporation of morphology and the plant's epidermal structure with orientation and growth position of phytoliths as significant elements in identification. The work of Metcalfe (1960) provides a perfect example of a biological classification based on his study of 200 grass species. Second, the morphological classification is used when phytoliths are disarticulated from plant tissue fragments and are found in isolation (Mulholland and Rapp 1992:67). This classification follows a hierarchical order by identifying different phytolith categories, including trichomes, stomatal complex, bulliform cells, epidermal groundmass cells rods, rectangles/squares, and silica-bodies composed of beveled pyramids, cones, rectangular boxes and cylinders (Mulholland and Rapp 1992:69).

Despite the distinctions between the biological and morphological approaches to the classification of phytoliths, it is still possible to use them in combination. For instance, the University of Missouri-Columbia uses a system of classification that incorporates both approaches (Pearsall and Dinan 1992). It consists of a hierarchical classification system with nine distinct order divisions, starting with broad categories related to the cellular origin of the phytoliths (Pearsall and Dinan 1992:39-40). The first order division consists of broad categories numbered 10, 20, 30...110, each representing a specific known anatomical origin, with the exception of the number 60 which is allotted to phytoliths from an unknown origin. Second order divisions are assigned Roman numerals and are based on morphological differences. Edge characteristics are given capital letters in the third level division of the classification scheme. Further, edge characteristics and surface texture is recorded using lower-case letter in the fourth order level of classification. The remaining five order levels within the classification scheme are based on additional morphological distinctions (Pearsall and Dinan 1992:39-400).

A classification based purely on morphological differences has been compiled using a scanning electron micrograph to determine variability in surface texture of sedge phytoliths (Ollendorf 1992). This approach demonstrates the variability inherent in the sedge genera phytoliths. Ollendorf's (1992) study also illustrates the importance of the scanning electron micrograph in refining the classification schemes established by looking through an ordinary microscope. Such work reflects upon the work remaining to refine and examine many phytolith classifications. Of course, the first step, especially for the archaeologist, must start in the field.

Field Sampling, analysis and interpretation

Collecting soil samples is an important step leading to the recovery and identification of phytoliths. Two field sampling strategies are employed by archaeologists: 1) samples are recovered horizontally across the excavated floor; and/or 2) vertically along the excavation profile. Phytolith data resulting from the two sampling methods offer different kinds of information. The vertical or column sampling method provides information related to changes in vegetation through time by identifying variations in phytolith types. A horizontal sampling reveals changes in vegetation types at a specific stratigraphic level. Plant exploitation activities may be obtained by employing a horizontal sampling strategy at a particular cultural level. These two methods have been used to address research questions relating to farming practices involving irrigation (Rosen 1987) as well as identifying buried paleosols (Pease 1967; Rapp and Hill 1998). As a general rule, vertical sampling is done every 5-10 cm, while horizontal sampling is dependent upon the extent of intrasite variability the researcher is willing to examine.

The collection of soil samples must take into consideration the four major factors affecting the deposition of phytoliths in soil sediments (Piperno 1988:141). First, the amount of phytoliths produced and deposited varies between plants. Comparative studies have demonstrated that domesticated plants produce lower quantities of phytolith than wild plants. Second, horizontal redeposition is a type of disturbance of the original phytolith contexts. In other words, the deposition of phytoliths occurs on the same stratigraphic level but is at a different location from the source. Third, natural and cultural disturbances can also redeposit phytolith vertically in space. Fourth, preservation is dependent upon the pH value of the soil matrix with more severe decomposition in acidic soils (Piperno 1988:141-147). Consequently, any horizontal and vertical disturbance must be identified and the phytolith production characteristics of most plants within the region recognized before any interpretation is attempted.

Collecting, identifying, and describing modern botanical specimens from the local area of the archaeological site are other important aspects of field sampling. Not only do these botanical samples provide a record of the modern vegetation but they also offer a database of phytolith varieties for comparative purposes. Whole plant specimens should be collected because, as mentioned earlier, a plant may generate a number of morphologically different phytoliths. Phytoliths recovered from the different segments of plants would illustrate the phytolith variability offering a more complete base for comparison.

Phytoliths are extracted from both soil and botanical samples recovered in the field. A detailed account of different phytolith recovery methods will not be presented in this paper. Instead, the reader is directed to Piperno's (1988) and Pearsall's (2000) handbooks where different approaches are listed, described and compared. Similarly, phytolith extraction procedures are also found in the works of Mulholland and Rau (1985), Fredlung (1986) and Carbone (1977). A discussion of laboratory procedures including the scanning, counting and documenting phytoliths from microscope slides is presented below.

An optical microscope is the most important piece of equipment in the analysis process. Magnification ranging between 200X-400X, a mechanical stage for fine movement of the slide, an eyepiece micrometer, and a polarized light (Pearsall 2000:414) are a prerequisite for the identification and counting of phytoliths. Ideally, many hours of strenuous observations through the microscope can be avoided by using a computer imaging system equipped with software for recording phytolith images. Lacking the imaging system, the documentation of morphologically different phytoliths can be done with a 35mm camera attached to the microscope (Pearsall and Dinan 1992). The author has produced excellent results with a digital camera taking photographs through the eyepiece of the microscope.

Scanning the slide for phytoliths is the first task in the analysis process and involves three steps: quick-scanning, short-cell scanning and diagnostic scanning (Pearsall 2000:446). Performed at 250X magnification, quick scanning allows for the identification of broad categories relating to the cellular origin of the phytoliths. Short cell and diagnostic scanning follow and consist of documenting the variability in phytoliths morphology, which can be identified to specific plants. Phytoliths are recorded and tallied on specially designed forms for reference and future comparative analysis. Maintaining consistency is very important for future identification and interpretation.

Phytolith counting procedures bear directly upon interpretation. For morphologically distinct phytoliths, most analysts use a predetermined number of counts per microscope slide, usually between 100-200 counts. That is, if the predetermined number is 100 then all morphologically distinct phytoliths are counted, stopping at 100. Percentages are used if the total phytolith count per slide falls below this predetermined number. Percentages can be presented in a diagram format illustrating the hierarchical level from which each analyzed sample originates. Moreover, these diagrams offer a quick visual reference to changes occurring in phytolith percentages from one sample to the next.

Identifying the phytoliths is often conducted at the same time as the counting process. The identification process can be done using previously published reference materials or by comparing phytoliths to those derived from a known biological sample. It is for this reason that a collection of plants from the local area of research is imperative. Often the identification involves the use of both methods.

Phytolith studies offer valuable information on the origins of agriculture and the dispersal of domesticated plant species throughout the world (Wilson 1982; Piperno 1984). Phytolith data have been used in discussions of domestication and origins of maize in the New World. For instance Piperno *et al.* (1985), made the fine distinction between cross-shaped maize phytoliths and cross-shaped grass phytoliths using a five-variable discriminant multivariate analysis. Their study revealed early occurrence of maize in the early preceramic period of Panama (7600 B.C.-6100 B.C.).

Correlates have also been made between phytoliths and agricultural technology used by different prehistoric groups. For instance, phytoliths were used to associate prehistoric fields, canal systems, soil mounding and terracing with wetland agriculture (Denevan 1982). Wetland agriculture can also be identified through changes in the frequencies of diatoms and sponge spicules offering information on soil drainage (Piperno 1988:180-181).

Perhaps the most important archaeological application of phytolith interpretation is in paleoecological reconstruction. Phytolith sequences, in conjunction with microfossil data sets and pollen offer the basis for the reconstruction of regional vegetation and climate. This approach is based on the direct correlation between plants, temperature and humidity. For instance, dry and hot periods are more conducive to the growth and spread of specific plant species that are identified archaeologically by an increase in their phytolith numbers. Unfavorable environmental conditions are observed by a decrease of phytoliths.

Other researchers incorporate studies of ceramic sourcing based on phytoliths presence in the clay fabric. Ranks and Bargielski havc looked at phytoliths as identifiable markers of Maya clay sources. Others have explored the removal of phytoliths from dental calculus as direct evidence of diet (Laluela Fox and Albert 1996). Some researchers have even been successful in the recovery of phytoliths from stone tools (Kealhofer *et al.*. 1999).

Phytolith analysis of soil samples from Dudeştii Vechi – Case Study

recovered from soil samples during the 2001 field season at the archaeological site of Movila lui Deciov, near the present day village of Dudeştii Vechi, Timiş county, Romania (Figure 1). This multicomponent site with two Starčevo culture occupations has come to be known simply as Dudeştii Vechi, and this name will be used henceforth in this paper.

This region of southeastern Europe was occupied by various Neolithic cultures starting with the Starčevo agriculturists dated circa 6100 B.C., a calibrated radiocarbon date obtained from the site of Grivac, Serbia (Manson 1995:69). Debates on the origins of the Starčevo culture persist to this day, some scholars arguing for migration from the Near East (Piggott 1965; Vencl 1986; Cauvin 1994) and others arguing for their origins from the local hunter-gatherers (Dennell 1983; Chapman 1994; Zvelebil 1986, 1995).

Starčevo chronological sytematics are based on ceramic sequences and vary from one researcher to the next. While most agree on temporal ceramic differences throughout the culture, disagreement still continues with regards to the number of cultural divisions. Milojčiæ (1950), and Lazarovici (1979), propose a four phase Starčevo ceramic sequence, while Arandeloviæ-Garašanin (1954) and Garašanin (1979) support a three part division. Absolute dates for these divisions are provided by Manson (1995:69-70) (Table 1).

Milojčić 1950 and Lazarovici 1979	Arandelović-Garašanin 1954 and Garašanin 1979	Radiocarbon Date (calibrated)
Starčevo IV	Starčevo III	ca. 5400-5100 B.C.
Starčevo III	Starčevo IIb	ca. 5650-5400 B.C.
Starčevo II	Starčevo IIa	ca. 5950-5650 B.C.
Starčevo I	Starčevo I	ca. 6100-5950 B.C.

Table 1: Chronology of the Starčevo culture (from Manson 1995:69-70).

Starčevo subsistence was based on domestic and wild plants and animals. Evidence of prehistoric economies from Starčevo-Grad, Divostin, Obre I, and Anzabegovo produced a list of domesticated cereals and legumes such as broom-corn millet, emmer, einkorn, club wheat, six-row barley, peas and lentils (Manson 1995:70; Whittle 1996:40). Wild plants identified include cherries, wild grapes, apples, hazelnuts, and acorns (Manson 1995:70). From faunal remains, wild animals identified include wild pig, brown bear, beaver, wolf, brown hare, fox, tortoise, catfish, pike, and carp while domesticates include dogs, cattle, sheep goats, and pigs (Manson 1995:70). A study of faunal remains from Dudeştii Vechi by El Susi (2002) shows the identified animal resources exploited at the site in a temporal perspective. Overall, wild and domesticated mammals predominate with 64.5% the total faunal assemblage (El Susi 2002: Tabel 7). The data from Dudeştii Vechi and other sites support a notion of different animal exploitation strategies by the Starčevo people.

Direct evidence for the exploitation of agricultural crops has been a shortcoming of archaeological research on the Starčevo culture. This is due to the rarity of research strategies directed towards plant subsistence research questions. The present case study is significant for it reflects upon plant subsistence and the local environmental.

Dudeştii Vechi is within an area of limited relief and is generally below 100 m asl (Chapman 1981:101). It has been prone to periodic flooding prior to flood-protection works undertaken in the 20th Century. Sedimentation from the periodic floods produced nutrient-rich soils making the area attractive for early agriculture. The site is in a modern agricultural field and rises 3 m over an area of 200 m in diameter. Gornea Aranca, the southern tributary of the Arnaka River which starts 40 km northeast of Dudeştii Vechi, is just north of the site. The Aranca River is a tributary of the Tisza River drainage system that empties into the Danube River. Present day vegetation is entirely composed of agricultural crops and weeds in comparison to the Postglacial vegetation cover which consisted of mixed oak forests, similar to those noted in Hungary (Zolymi 1953).

Dudeştii Vechi is an important stratified site first excavated at the turn of the 20th Century. Excavations by the local collector Nagy Gyula Kislegi in 1906 and 1907 resulted in the recovery of many complete artifacts currently housed at Muzeul Banatului, Timisoara, Romania. Kislegi recognized, but did not identify, three cultural occupations: 1) a layer of ash, pottery and animal bones 250 cm below the surface; 2) cultural material 150 cm below the surface; and 3) more cultural material 50 cm below the surface (Kislegi 1909). Test excavations in 2000 and 2001 identified two Starčevo occupations. The depth of the cultural layer associated with each of the Starčevo occupations varies across the site and depends on the excavation location in relation to the tell. At the location sampled for phytoliths, the earliest Starčevo occupation was between 140 cm and 160 cm below the surface. At this level the cultural layer consisted of artifacts, charcoal, ash and fish scales. A later Starčevo occupation level was identified between 95 and 110 cm below the surface represented by a house floor feature and artifacts. The lowest cultural occupation is identical to the one Kislegi describes at 250 cm, illustrating the variability in topography at the time of occupation. Located south of Kislegi's 1906-1907 excavations, the test trenches of 2000 - 2001 have a shallower stratigraphy because they are on the periphery of the settlement and therefore on the flatter portions of the site..

The discovery of two Starčevo cultural layers makes Dudeştii Vechi an important site for a temporal analysis of culture change. Preliminary examination of pottery materials suggest an occupation of the site beginning in the Starčevo IIB period and ending in Starčevo IVA period, following the chronological systematics of Lazarovici (1979:55). This period of occupation encompasses the timeframe of 5950-5100 B.C., corresponding to Manson's (1995:69) calibrated dates spanning from Starčevo IIa to Starčevo III period.

Methodology

Eight soil samples were collected from Dudeştii Vechi during the 2001 excavation field season. A vertical soil sample collection strategy was employed with samples collected from the excavated trench profiles at depths ranging from 85 cm to 210 cm below the surface. This approach offered the best assessment of vegetation changes through time at the site. Of particular importance was the collection of soil samples from the two Starčevo cultural levels.

Phytolith extraction from the Dudeştii Vechi soil samples followed standard methods used at the University of Calgary Paleoethnobotany laboratory. These methods are similar to those of Pipcrno (1988) and consist of five steps. The first processing step is the sieving 4-6 g of each soil sample through a 0.5 mm screen. Second, the screened soil was then washed with a 1 molar HCl to remove all carbonate inclusions. Third, the fine silts were removed by suspending the soil sediment in a calgon solution. Fourth, polytungstate with a specific gravity of 2.3 was used to suspend and separate the phytoliths from the soil matrix. Upon siphoning off the polytungstate solution, distilled water was used to wash the samples and then recover the remaining phytoliths, which were mounted on slides with entellan.

Scanning of the slides containing the phytoliths was the next step in the analysis. The identification process was made in the absence of a comparative collection. As of yet, comparative phytolith collection for the Dudeştii Vechi area does not exist at this time. Instead, the means for phytolith identification in the present study is based on numerous published studies on the morphology of cereal plants.

Rather than focus on individual phytoliths, it was decided to concentrate on the classification and identification of multi-celled or aggregate phytoliths. The focus on aggregates is adopted here because a more accurate comparison with published references can be achieved. This study relies on published works of Ball *et al.* (1999), Rosen (1993, 1992), Ball *et al.* (1993), Kaplan *et al.* (1992), Hodson and Sangster (1988), Hayward and Parry (1980), and Geis (1978). Most samples processed from Dudeştii Vechi contain a large number of both individual and aggregate phytoliths. Aggregate phytoliths were counted during the systematic scanning of each slide under a 200X magnification. In addition, aggregate phytoliths were photographed under a 500X magnification with a digital camera and the morphological identification was done using these digital images.

Results

All aggregates were counted during the scanning process of the eight thin-section slides. These counts reveal an association between the two Starčevo cultural levels and high aggregate number (Figure 2). Specifically, there were 167 phytolith aggregates on the slide representing the soil sample recovered from 140 cm below the surface. This corresponds with the lowest Starčevo occupation level. Similarly, 172 aggregates were counted on the thin-section slide representing the soils sample recovered from 100 cm below the surface and corresponding to the highest upper Starčevo occupation level. Another sample associated with the upper Starčevo occupation was recovered from 95 cm below the surface and contained 117 aggregates.

When examining phytolith aggregates, attributes such as size, edge, and surface characteristics of phytoliths were considered leading to the creation of 18 morphological aggregate types (Table 1: Figures 3 to 20). Exceptional preservation of the phytoliths allowed the recording of some detailed morphological characteristics. In several instances type 5 aggregates were observed to occur together with types 9 and 7 aggregates. Morphological changes occur both horizontally and vertically through the aggregates. While some phytoliths are superimposed on morphologically different phytoliths, others change from one type to another, when viewed on the same plane.

Ten of the 18 aggregates have been tentatively identified from published sources and are listed in Table 1. Three aggregate types (Types 3, 15, and 17) are possible hair cells, similar to those illustrated by Pearsall and Dinan (1992) and Bozarth (1992). Type 2 aggregates are identified as barley (*Hordeum*) phytoliths illustrated in Rosen (1992). Three aggregate types (Types 5, 7, and 9) are identified as wheat (*Triticum*) from similar references observed in Ball *et al.* (1999, 1996 and 1993) and Rosen (1993 and 1992). Type 10 aggregates are identified as possible cereal straw as illustrated in Rosen (1993). Phytoliths of cereals are particularly important in this study for they offer the platform for a discussion of plant use through time.

Graphs illustrating the overall frequency of aggregate types in relation to stratigraphy offer a visual interpretation of plant use and vegetation changes at Dudeştii Vechi. Individual graphs appear to mirror the overall counts illustrated in Figure 2. That is, the frequencies of aggregate types are low in the deepest stratigraphic levels and tend to increase with less depth below the surface, reaching a bimodal distribution with maximum peaks represented at both Starčevo occupation levels.

Results of the aggregate distributions are presented and discussed below. Barley appears in the stratigraphic record in the lowest Starčevo occupation level where most aggregates are found (Figure 21). There is a sharp decline in frequency between the cultural components at 120 cm below the surface. The frequency of barley again increases 100 cm below the surface, reaching a second peak at 95 cm below the surface corresponding with the top of the later Starčevo component.

Similar trends are observed in the frequencies of the three wheat aggregate types (Figures 22-24). Type 5 aggregates are most frequent at 140 cm below the surface level (Figure 22). Their frequency is low at 120 cm below the surface but then increases in the later Starčevo component. Type 7 shows a steady increase in frequency starting in the early Starčevo occupation, reaching its peak at 100 and 95 cm below the surface, again corresponding with the later Starčevo cultural component (Figure 23). Type 9 aggregate frequencies are binomially distributed with one peak occurring at 140 cm below the surface the other at 100 cm below the surface, corresponding to the two Starčevo occupation levels. The remaining phytolith aggregate types have similar distribution patterns, also appearing most frequently in the two Starčevo occupation levels.

Discussion

It must be stressed that this research is biased towards cereal crops. Legumes such as lentils (*Lens culinaris*), broadbean (*Vicia faba*), and pea (*Pisum arvense*) were also identified from paleobotanical remains in some Starčevo sites. Unfortunately, very little phytolith research has been done on legumes making any archaeological investigation of soil legume phytoliths at Dudeştii Vechi difficult. Phytolith research on cereals has been more rigorous resulting in a number of publications used in this identification process.

A most intriguing find during this study has been the extraordinary preservation of aggregate phytoliths. Addressing this phenomenon takes us to previous research on the association of surface and ground moisture to the frequency of phytolith aggregates. The relationship between surface water, ground water and phytolith yields has been investigated and suggested by Rosen (1993, 1992), stating that „preliminary tests...show that an increase in surface and ground water does induce higher phytolith yields in semiarid environments:" (Rosen 1993:169). While Rosen's interpretation is geared for semiarid environments, it is likely that similar factors may have been responsible for the abundance of aggregate phytoliths at Dudeştii Vechi. Water at Dudeştii Vechi was in abundance given the close proximity to the Gornea Aranca drainage channel. In addition, low-lying areas south and east of the site may have been prone to seasonal flooding. The relatively high ground/surface humidity is reflected in the abundance of the aggregate phytoliths. However, it is difficult to ascertain at this time if this was due to natural or cultural factors. For future archaeological research at Dudeştii Vechi, investigations should also pursue the question of agricultural practices involving irrigation.

Another intriguing find is the abrupt decline in both aggregate and individual phytoliths below the earliest Starčevo occupation. This decline begins at 170 cm below the surface. In conjunction with this decline is an increase in the quantity of microscopic charcoal. Piperno (1990, 1991 and 1993) used phytolith data to address questions of land use. In one study (Piperno 1993) she interprets the increase in microscopic charcoal with a slash-and-burn method of land clearing. In view of this study it can be suggested that anthropogenic deforestation using fire took place during the earliest Starčevo occupation. Pollen data for the Dudeştii Vechi region do not exist at this time, but a pollen record from the neighboring Hungary indicates a postglacial vegetation cover of mixed oak forests (Zolymi 1953). Burned acorns, recovered from the lowest Starčevo occupation level at Dudeştii Vechi, provide testimony to the presence of such a forest. In forested environments overall phytolith production is considerably reduced. Archaeological evidence of probable anthropogenic activity is seen in the many partial and complete stone tools recovered from the earliest Starčevo levels at Dudeştii Vechi. Most of the 150 polished stone axes, hammers and chisels recovered by Kislegi during the 1906-1907 excavations originated from the lowest Starčevo cultural levels (Kislegi 1909). An additional six stone axes were recovered during the 2000 and 2001 test excavation. These tools may have been used in felling the trees. Thus, the phytolith data, in conjunction with artifact data support the idea of land clearing for agricultural purposes by the earliest Starčevo people at Dudeştii Vechi.

CONCLUSION

This paper has offered a brief introduction to phytolith research and presented a case study that focused on the analysis of phytolith aggregates recovered from soil samples at the multicomponent Starčevo site of Dudeştii Vechi, Romania. It has provided only a glimpse of the potential application of phytolith research to archaeological investigations. Phytolith studies make up an area of research still in its infancy. Additional research on phytolith typology and morphometric variability within individual plants have the potential of laying the groundwork for the identification of phytoliths derived from different parts of the plant resulting in possible inferences regarding activity areas within archaeological sites. Comparative material of other plants, such as lentil (*Lens* culinaris), broadbean (*Vicia* faba), and pea (*Pisum* arvense), are desperately needed for southeastern Europe if questions related to the early agricultural practices are to be addressed.

For Dudeştii Vechi, this research has identified evidence for a plant subsistence economy based on cereals. When combined with the faunal remains it confirms some aspects of the known Starčevo subsistence practices identified at other sites. The significance of this find lies in the actual hard evidence that can be used in comparative research, focusing on subsistence economies in a regional context. In addition, land clearing and the probable irrigation practices arc issues of debate by researchers working on the early Neolithic of southeastern Europe. The archaeological evidence from Dudeştii Vechi contributes to this debate. It is anticipated that future macrobotanical analysis at this site will corroborate the findings of this research and bring a finer resolution to the early Neolithic subsistence economy and environmental manipulation.

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FITOLITELE ŞI ARHEOLOGIA: STUDIU DE CAZ ÎN AŞEZAREA NEOLITICĂ TIMPURIE DE LA DUDEŞTII VECHI, ROMÂNIA

Rezumat

Identificarea şi interpretarea fitolitelor recuperate din probele de sol arheologic a intrat în practica ştiinţifică în ultimele decenii. Fitolitele sunt minerale microscopice formate din structuri de siliciu care se găsesc în corpul plantelor şi care pot fi identificate după dispariţia respectivelor plante.

Scopul acestui studiu este de a prezenta metoda analizei fitolitelor aplicată pe un caz particular, în aşezarea neolitică timpurie de la Dudeştii Vechi – Movila lui Deciov, cu relevarea contextului economic şi ambiental.

Cercetarea fitolitelor a demonstrat existenţa în acest sit a unei subzistenţe bazate pe cereale.

Type	Margins	Surface	Form	Comments	Possible identification	Reference
1	Smooth	Smooth	Quadrilateral	Length is 2-4 times the width (less than 60 microns)	*Panicum*	Geis 1978
2	Undulating	Uneven	Quadrilateral	Length is greater than 4 times the width	*Hordeum*	Rosen 1992
3	Smooth	Smooth	Non-quadrilateral		Hair Cell	Dinan and Pearsall 1992; Bozarth 1992
4	Smooth	Smooth	Quadrilateral	Length is more than 4 times the width with channels between phytoliths	n/a	
5	Smooth	Smooth and grooved	Oval	In some cases occur in association with long quadrilateral serrated phytoliths	*Triticum*	Ball et al 1993, 1996
6	Sinuous	Smooth	Quadrilateral	Length is more than 4 times the width	n/a	
7	Sinuous	Smooth	Quadrilateral	Length is 2-4 times the width (less than 60 microns)	*Triticum*	Ball et al 1999; 1996
8	Sinuous	Uneven	Quadrilateral	Length is more than 4 times the width	n/a	
9	Dentate	Uneven	Quadrilateral	Length is 2-4 times the width (less than 60 microns) - highly serrated edges	*Triticum*	Rosen 1993, 1992
10	Smooth	Smooth	Quadrilateral	Length is greater than 4 times the width	Possible cereal straw	Rosen 1993
11	Smooth	Smooth	Wedge	Like orange slices arranged in a circular pattern	n/a	
12	Smooth	Smooth	Roughly oval		*Panicum*	Geis 1978
13	Undulating	Smooth	Quadrilateral	Highly serrated long edges - serrations rounded	n/a	
14	Undulating	Smooth	Quadrilateral	Highly serrated long edges - serrations pointed	n/a	
15	Smooth	Smooth	Non-quadrilateral		Hair Cell	Bozarth 1992
16	Slightly undulating	Smooth	Quadrilateral	Length is 2-4 times the width	n/a	
17	Serrated	Uneven	Oval		Possible Hair Cell	
18	Smooth	Smooth	Round		n/a	

Table 1: Description of aggregate types from Dudestii Vechi

Figure 1: Satellite and aerial views showing the location of the Early Neolithic archaeological site Dudestii Vechi

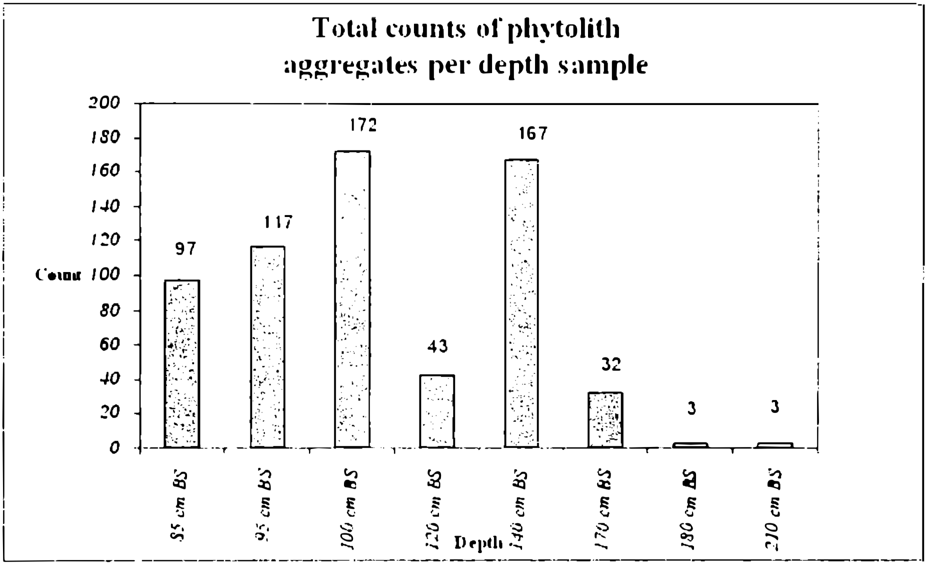

Figure 2: Total counts of phytolith aggregates at Dudeştii Vechi

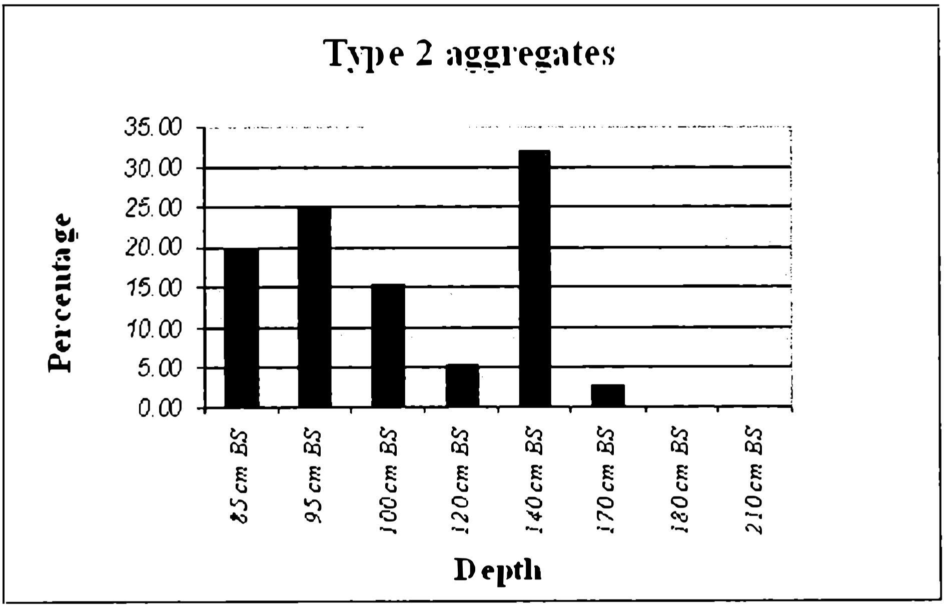

Figure 21: Frequency of type 2 aggregates (barley) in relation to stratigraphy

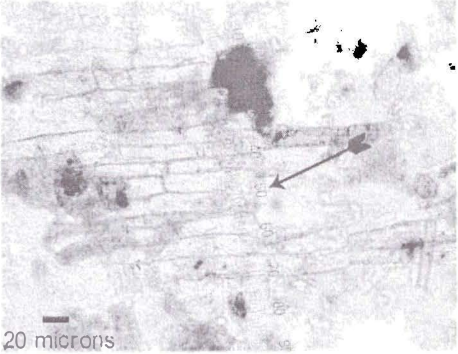

Figure 3: Type 1 aggregate - smooth quadrilateral with a smooth surface and the length is 2-4 times the width and less than 60 microns

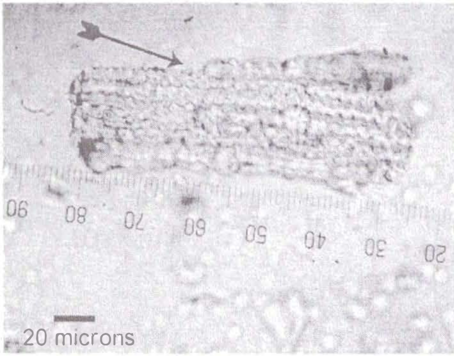

Figure 4: Type 2 barley husk aggregate - undulating quadrilateral with an uneven surface and the length is greater than 4 times the width

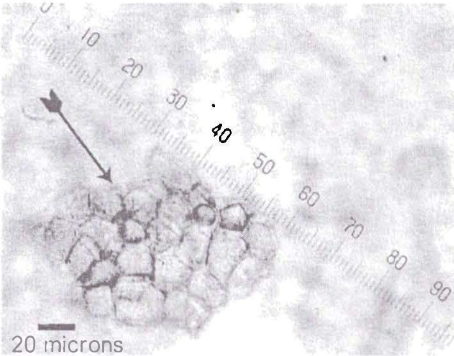

Figure 5: Type 3 hair cell aggregate - smooth non-quadrilateral with a smooth surface

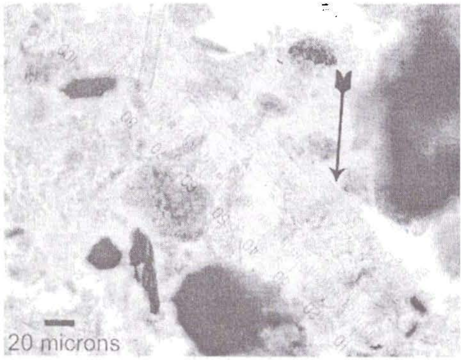

Figure 6: Type 4 aggregate - smooth quadrilateral with a smooth surface and fine channels betwen them and the length is greateater than 4 times the width

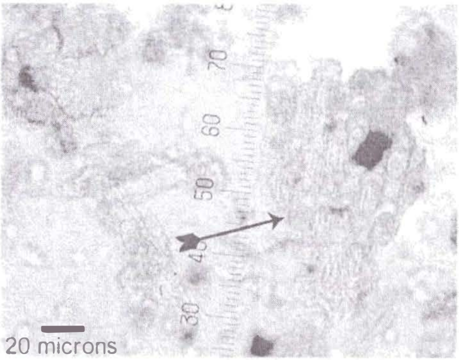

Figure 7: Type 5 silicified stomatal aparatus of wheat aggregate - smooth oval surface with a smooth and grooved surface

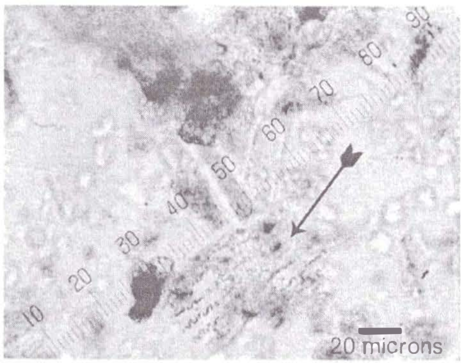

Figure 8: Type 6 aggregate - sinuous quadrilateral with a smooth surface and the length is more than 4 times the width

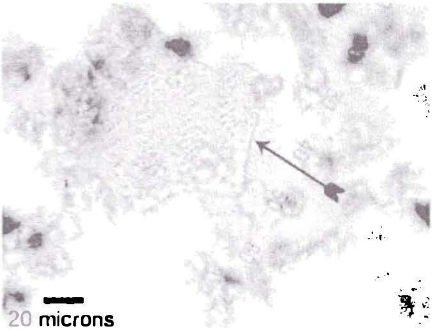

Figure 9: Type 7 wheat aggregate - sinuous quadrilateral with a smooth surface and the length is 2-4 times the width

Figure 10: Type 8 aggregate - sinuous quadrilateral with an uneven surface and the length is 2-4 times the width

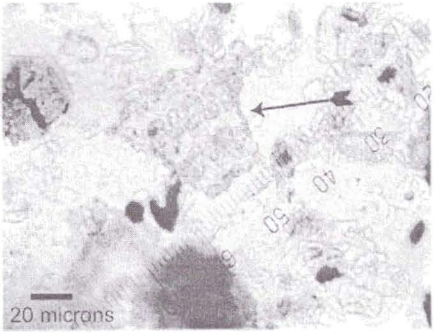

Figure 11: Type 9 wheat aggregate - dentate quadrilateral with highly serrated edges, uneven surface and the length is 2-4 times the width

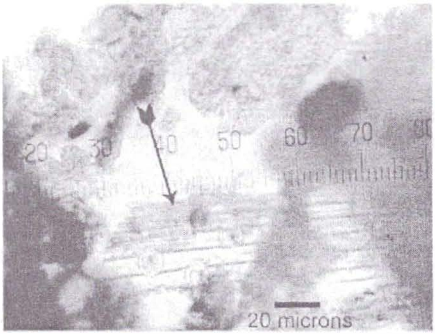

Figure 12: Type 10 cereal straw aggregate - smooth quadrilateral with a smooth surface and the length is 4 times the width

Figure 13: Type 11 aggregate - smooth wedge with a smooth surface

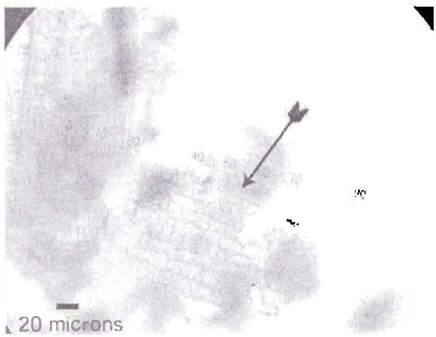

Figure 14: Type 12 aggregate - smooth oval with a smooth surface

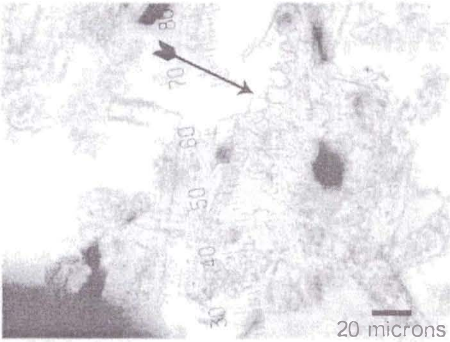

Figure 15: Type 13 aggregate - undulating quadrilateral with a smooth surface and highly serrated edges

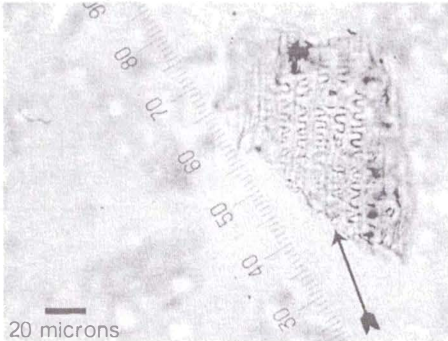

Figure 16: Type 14 aggregate - undulating quadrilateral with a smooth surface with highly serrated and pointed edges

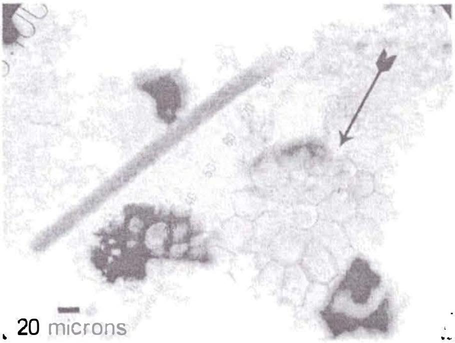

Figure 17: Type 15 hair cell aggregate - smooth non-quadrilateral with a smooth surface

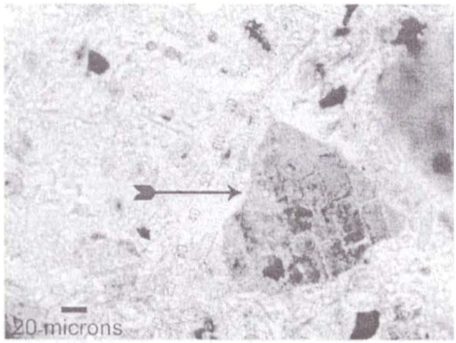

Figure 18: Type 16 aggregate - smooth quadrilateral with a smooth surface and the length is 2-4 times the width

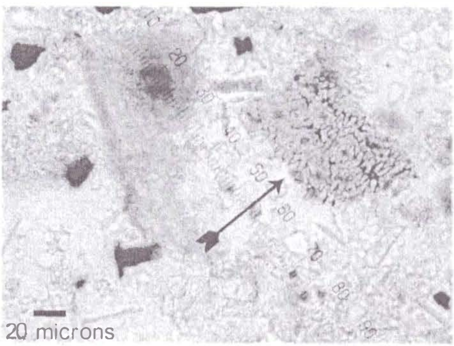

Figure 19: Type 17 possible hair cell aggregate - serrated oval with an uneven surface

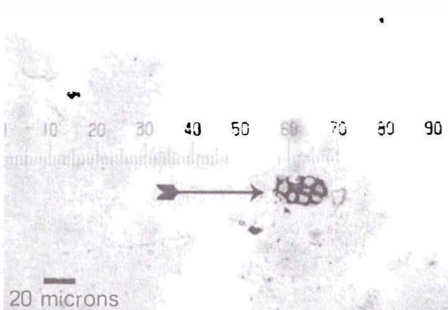

Figure 20: Type 18 aggregate - smooth round with a smooth surface

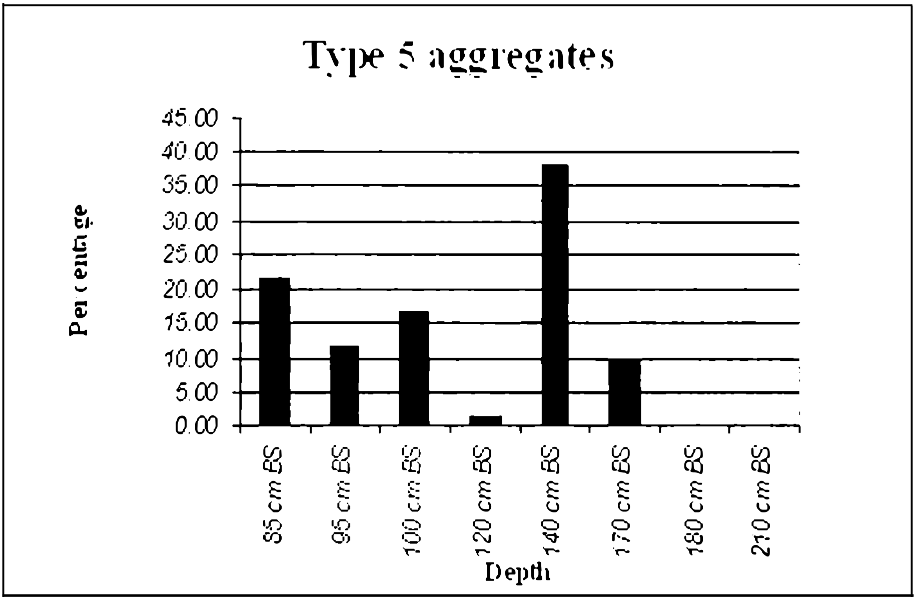

Figure 24: Type 5 (wheat) aggregate frequencies

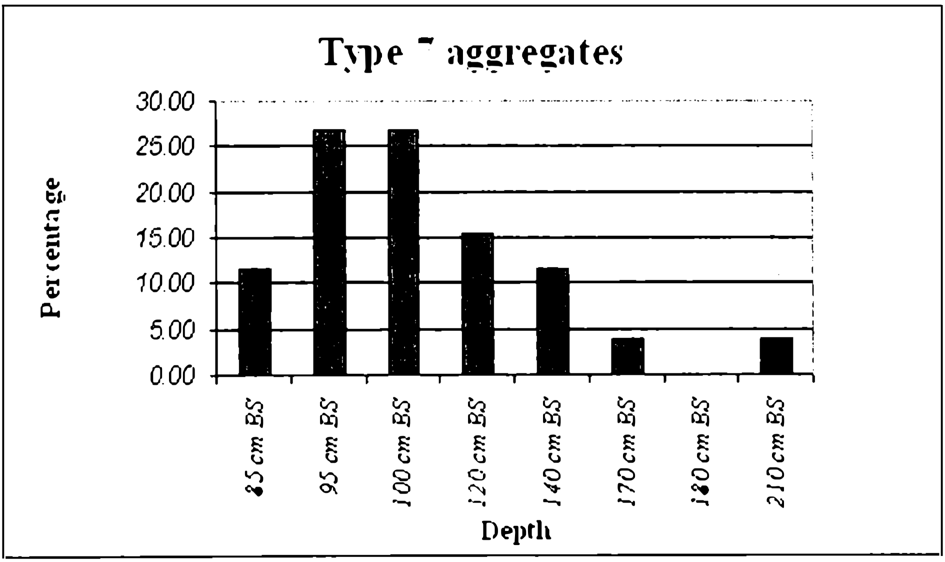

Figure 23: Frequency of type 7 (wheat) aggregates in relation to stratigraphy

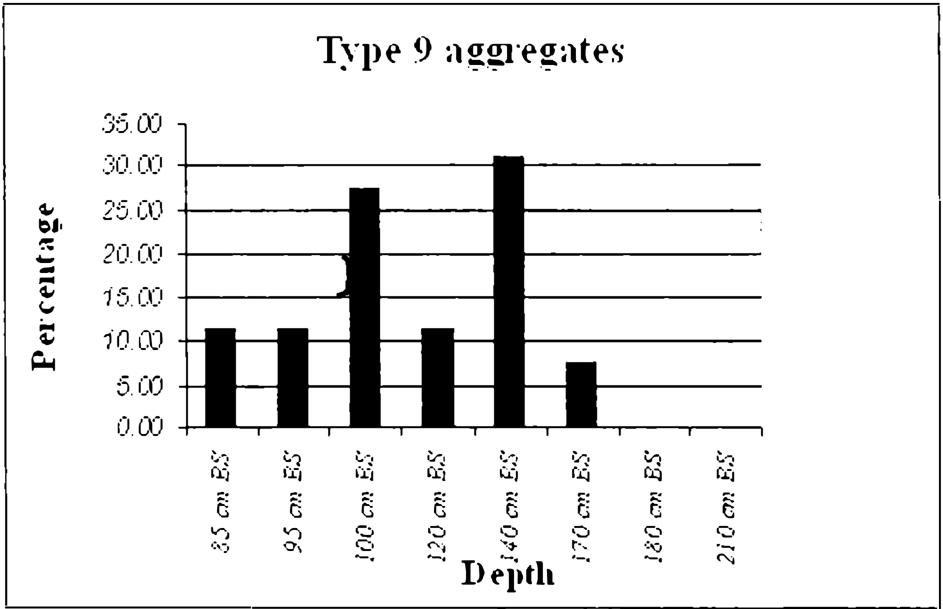

Figure 22: Type 9 (wheat) aggregate frequencies