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NOTES ON THE SPECIFIC DETERMINATION OF THE GENUS *TETRATAXIS*

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ABSTRACT—All the species belonging to the genus *Tetrataxis* are examined on the basis of both their morphological measurement data and type figures, especially with regard to the orientation of thin sections used for describing a given taxon. As a result, it is revealed that 34 species out of 88 species examined ought to be re-described with the use of properly oriented thin sections.

Key words: Species, determination, *Tetrataxis*

MORPHOLOGICAL MEASUREMENTS OF *TETRATAXIS*

Upper Paleozoic foraminifers characterized by a trochospiral conic shell with double layered calcareous walls were systematized as the family Tetrataxidae (Rauser-Chernoussova and Fursenko, 1959; Loeblich and Tappan, 1964). Subsequently, the two families Pseudotaxidae Mamet, 1974 (single microgranular calcareous wall) and Valvulinellidae Loeblich and Tappan, 1984 (chambers subdivided by partitions) were defined in addition to the above family. Moreover, St. Jean (1957) and Nestler and Langbein (1976) paleontologically studied thin sections of loose specimens in detail, and they suggest that the orientation of thin sections is important for a paleontological study of *Tetrataxis*.

In the paleontological synthesis of Foraminiferida by Loeblich and Tappan (1988), the family Tetrataxidae is defined to comprise three genera, *Tetrataxis*, *Polytaxis* and *Globotetrataxis*, which are all characterized by double-layered walls and conical shells with trochospirally adding chamber arrangements. The last mentioned genus, which is limited to the Upper Visean in stratigraphical occurrence, differs from the others in its convex base formed with a large hemispherical last chamber. *Polytaxis* is characterized by a very low conic shell with four or more chambers per whorl. The first appearance of *Polytaxis* is in the Early Permian, and its phylogenetic lineage shows that this genus is an evolutionary form of a low conical shell species of the Carboniferous *Tetrataxis* (Okimura, 1989).

Tetrataxis observed in thin section could take a wide range of outlines from circular to subtriangular depending on the orientation of cut through a cone (Fig. 1), because this genus has a shell of typical cone shape. Accordingly, the thin-section study of *Tetrataxis* must be done by making at least two properly oriented cross sections which would enable description of true morphological characteristics; one drawing a triangle (axial section) and the other a circle (horizontal or basal section) (Fig. 1). True shell sizes and apical angles can only be measured

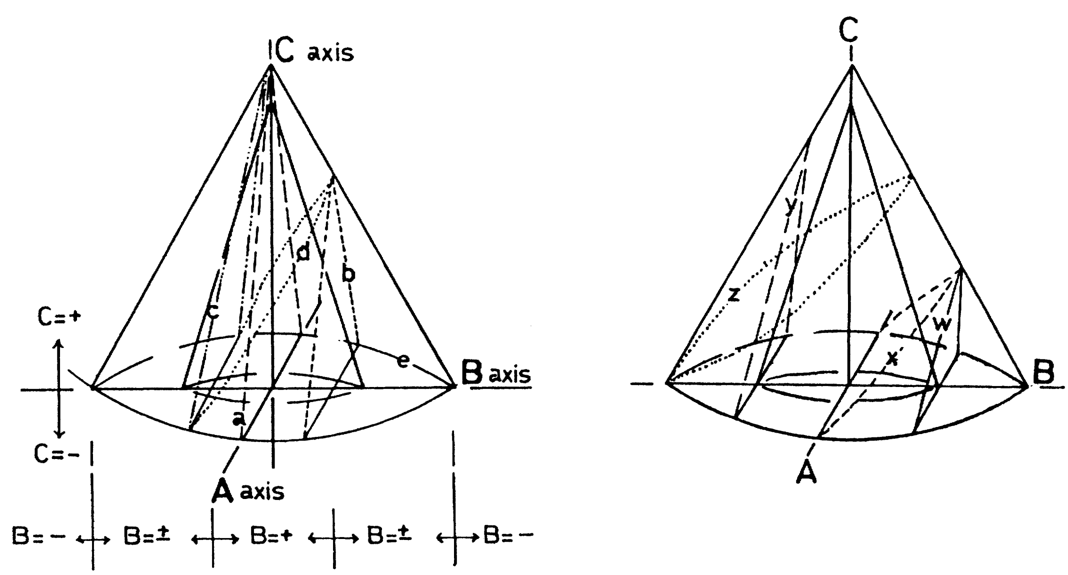

Fig. 1. Orientation of *Tetrataxis* in thin section.

Table 1. Measurements of all the species referred to the genus *Tetrataxis* (alphabetically arranged).

Species	Section	Width height (mm)	Apical angle (degree)	System -Stage
Tetrataxis acutiformis Potievskaya (1958)	=/*n*/Ap	0.58–0.90 0.40–0.58	not given	Bashkirian
**T. acutus* Durkina (1959)	nearly =/−*n*/*x*	0.51–0.80 0.60–0.70	45–60	Up. Visean
T. angusta Vissarionova (1948)	=/*n*/*x*	0.35–0.67 0.68	60–74	Visean- L. Penn.
**T. angusta serpukhovensis* Reitlinger (1950)	=/*n*/*x* =/−*n*/*x*	0.5 0.51	55–60	Moscovian
T. barkhatovae condrusina Conil et Lys (1964)	=/*n*/*x* others	0.97–1.3 0.75–1.3	55–65	Up. Visean
T. barkhatovae pigra Conil et Lys (1964)	=/*n*/*x*	0.6 0.42–0.50	60–70	Up. Visean
T. bashkirica Morozova (1949)	nearly =/*n*/*x*	1.8 0.86	120	L. Permian
**T. beschevensis* Potievskaya (1962)	=/*n*/*x*?	1.1 0.68	not given	Bashkirian
T.biconvexa Jean (1957)	/90/	1.31 0.64	110	M. Penn.
T. compactus Conil et Lys (1964)	=/−*n*/*x*	0.475–0.5 0.4–0.425	convex cone	Up. Visean
T. conciliatus Ganelina (1956)	=/*n*/Ap	0.38 0.28	89	Up. Visean
T. conica Ehrenberg (1854)	/90/	1.11 0.66	60–81 (after Lee, 1937)	Visean- Permian
**T. conica* var. *lata* Spandel (1901)	=/*n* BA/*x*	0.45–0.48 0.18–0.24	90–101 (after Del. et Marie)	Permian
T. conica var. *gibba* Moller (1879)	=/*n*/*x*	0.28–1.0 0.22–0.81	75–80	Visean
T. conili Pelhate (1967)	=/*n*/Ap	0.875 0.51	65	Visean
T. corona Cushman et Waters (1928)	=/*n*/*x*	0.49 0.21	100 (after St. Jean)	Carbonif.
**T. corona* var. *pauperata* Warthin (1930)	=/*n* BA/*x*	0.5 0.2	103	Carbonif.- Permian
T. cummulosa Lee (1937)	=/n/Ap	0.5 0.25	92	Carbonif.
**T. curviseptata* Morozova (1949)	=/n/*x*	0.3–0.55 0.25–0.46	60–70	Carbonif.- Permian
**T. curviseptata* var. *moderata* Morozova (1949)	=/*n*/*x*	0.76 0.57	80	Permian
**T. deccurens* (Brady)(1876) after Del. et Marie	*n*/*n* BA/*x*	1.00 0.13	151 (after Del. et Marie)	Visean- Permian
T. dentata Vissarionova (1948)	=/+*n*/Ap	0.34–0.54 0.26–0.39	90–100	Visean
**T. dentata* var. *magna* Vissarionova (1948)	=/*n* BA/*x*	0.47–0.75 0.36–0.66	90	Visean
T. deppressa Conil et Lys (1964)	=/*n*/*x*	1.0 0.45	95–100 conv. cone	Visean
**T. digna Glozdilova et* Levedeva (1954)	=/*n* BA/*x*	0.48–0.52 0.3–0.34	85–90	Tournaisian
T. donetzica Putra (1956)	=/*n*/Ap	0.42–0.62 0.25–0.3	100–110	Carbonif.

to be continued...

Species	Section	Width height (mm)	Apical angle (degree)	System -Stage
T. elegans Suleimanov (1949)	=/+n/x	1.56 1.09	pagoda form	Carbonif.
T. elegans Conil et Lys (1964)	∞/90/∞	0.8 0.47	pagoda form	Up. Visean
T. eomaxima Putra (1956)	=/n/x	1.0–1.2 0.4–0.5	110	Carbonif.
T. exornatus Conil et Lys (1964)	=/+n/x	1.0 0.65	65–75	Up. Visean
T. extensa Potievskaya (1964)	=/n/x	0.5 0.15	110	Carbonif.
T. fluxus Conil et Lys (1964)	=/n/x	0.37 0.42	55	Up. Visean
T. gigas Brazhnikova (1956)	=/90/=	0.52–0.8 0.42–0.77	bell shape (after Bogush et Yuf.)	Visean
T. gradi Conil et Lys (1964)	=/n+/x	0.72–1.05 0.37–0.5	85 convex cone	Up. Visean
T. hemiovoides Morozova (1949)	=/n/x	1.26 0.9	80–90 bell shape	Carbonif.
**T. hemispherica* Morozova (1949)	=/n BA/x	0.94 0.5	80–90 concave cone	Carbonif.
**T. hemispherica* var. *elongata* Morozova (1949)	=/−n/x	0.8–0.9 0.66–1.0	bell shape	Carbonif.- Permian
**T. hemispherica* var. *meridionalis* Morozova (1949)	=/n BA/x	1.07 0.56	80–90	Carbonif.
T. immatura Glozdilova Lebedeva (1954)	=/n/x	0.3–0.37 0.27–0.3	70–80 slightly conc. cone	Tournaisian
**T. irregularis* Morozova (1949)	=/n BA/x	0.61–1.52 0.4–0.83	80–90	Carbonif.
**T. ishmica* Durkina (1959)	=/n BA/x	0.88–1.21 0.59–0.81	70–75	Up. Visean
T. labiata Jean (1957)	/90/	1.31 0.64	90–100	Carbonif.
T. lata Bogush et Yuferev (1962)	=/n/Ap	0.8–1.62 0.3–0.8	93–111	Visean
T. magna (Vissarionova) (1948)	=/n/x	0.57–0.69 0.41–0.53	67	Up. Visean
**T. media* Vissarionova (1948)	=/n BA/x	0.45–0.75 0.32–0.35	65–100	Visean
**T. milsapensis* Cushman et Waters (1928)	sketch fig.	0.98 0.7	60 (isolated specimens)	Carbonif.
**T. minima* Lee et Chen (1930)	=/n BA/x	0.35–0.58 0.23–0.31	93	Visean
T. minima var. *latispiralis* Reit. (1950)	=/n/x	0.78 0.38	not given	Bashkirian
T. minima var. *mosquensis* Reit. (1950)	=/n/x	0.45–0.47 0.23–0.27	72	Moscovian
T. nana Morozova (1949)	=/n/Ap	0.5–0.6 0.35–0.42	70	Permian
T. numerabilis Reitlinger (1950)	=/n/=	0.74–0.81 0.59–0.68	bell shape	Carbonif.
T. obliqcus Conil et Lys (1964)	=/n/x	1.15 0.7	70–80 concave cone	Tournaisian
T. obtusa Malakhova (1956)	=/+n/x	0.39 0.49	bell shape (after Braz. et Vdovenko)	Visean
T. pagodaformis Lee et Chen (1937) slight. obliq.	=/n/Ap	1.05 0.9	67 pagoda-form	Carbonif.

to be continued...

Species	Section	Width height (mm)	Apical angle (degree)	System -Stage
**T. pallae* Conil et Lys (1964)	=/*n* BA/*x*	1.25–1.5 0.6–0.76	80–95	Up. Visean
T. palaeotrochus Brady (1876)	=/+*n*/*x*	0.8 0.6	60 (after Del. et Mar.)	Carbonif.-Permian
**T. palaeotrochus* var. compressa (Brady) (1876)	sketch fig.	0.8 0.64	60	Carbonif.-Permian
T. paraconica Reitlinger (1950)	=/*n*/Ap	0.78–0.9 not given	70	Visean
**T. paraminima* Vissarionova (1948)	=/*n* BA/*x*	0.3–0.42 0.42–0.68	65–80	Tournaisian
**T. paraminima* var. *aperta* Conil et Lys (1964)	=/*n* BA/*x*	0.65–0.92 0.31–0.52	85–90	Up. Visean
T. paraminima var. *paraminima* Vissarionova (1948)	=/*n* BA/*x*	0.35–0.57 0.3–0.52	76–88	Carbonif.
T. paraminima var. *paraminima* Conil et Lys (1964)	=/+*n*/*x*	0.47–0.75 0.3–0.47	65–75	Up. Visean
T. parviconica Lee et Chen (1930)	=/*n*/*x*	0.92 0.44	91 concave cone	Carb.-Permian
T. perifida Malakhova (1965)	=/*n*/*x* (*n* BA)	0.44 0.33	not given (after Braz. et Vdovenko)	Visean
T. petasi Conil et Lys (1964)	=/*n*/*x*	0.61 0.35–0.5	45 nearly pagoda-form	Up. Visean
**T. plana* Morozova (1949)	=/*n* BA/*x*	1.2–1.32 0.38–0.52	120–130	Carbonif.
T. planocula Lee et Chen (1930)	=/*n* BA/*x*	0.33 0.15	120	Carbonif.-Permian
T. planoseptata Morozova (1949)	=/*n*/Ap	0.93 0.44	70–80	Permian
**T. planulata* Morozova (1949)	=/*n* BA/*x*	0.99–1.11 0.34–0.42	115–125	Carbonif.
**T. plicata* (Brady) (1876)	sketch fig.	0.5 0.25	low cone	Visean-(Moscov.)
T. postminima Potievskaya (1962)	=/+*n*/*x*	0.72 0.33	90–95	Permian
T. pressulus Malakhova (1956)	=/*n* BA/*x*	0.8–0.96 0.32–0.5	100–115 (after Con. et Lys)	L. Carbonif.
T. pressulus var. *gigantea* Conil et Lys (1964)	=/*n*/*x*	1.6–2.0 0.65–0.8	115 low cone	Visean
T. pussilla Golubchov (1957)	=/*n*/Ap	0.6 0.4	80	Visean
T. quasiconica Brazhnikova (1956)	/90/	0.5 0.33	60–80 (after Golubchov)	Visean
T. quasiconica var. *plana* Golubchov (1957)	=/+*n*/*x*	0.46 0.3	90	Visean
**T. rudis* (Brady) (1876)	sketch fig.	0.75	plano-convex cone	Carbonif.
**T. rugosus* Conil et Lys (1964)	=/*n* BA/*x*	1.4–1.6 0.77–0.8	100	Visean
**T. schellwieni* Ozawa (1924)	=−*n*/*x*	1.0 1.0	60 bell shape	Permian
**T. scutella* Cushman et Waters (1928)	sketch fig.	0.8 0.12	very low cone	Carbonif.
T. secunda Zolotova et Igenin (1967)	=/*n*/Ap	0.31–0.46 0.14–0.20	85–90	Carbonif.

to be continued...

Species	Section	Width height (mm)	Apical angle (degree)	System -Stage
* *T. shikhanensis* Morozova (1949)	=/*n*/*x*	0.81–0.83 0.62	65–80	Permian
* *T. subconica* Morozova (1949)	=/*n*/*x*	0.44–0.71 0.32–0.65	60–70	Visean
* *T. subcylindricus* Conil et Lys (1964)	=/−*n*/*x*	0.45–0.6 0.65–0.92	bell-shape	Up. Visean
* *T. submedia* Brazhnikova (1956)	=/*n* BA/*x*	0.53–0.6 0.45	65–70 (after Golubchov)	Carbonif.
* *T. submedia* var. *quasodemtata* Golubchov (1957)	/*n*/	0.3 0.2	70	Carbonif.
T. susaicus Malakhova (1956)	=/90/=	0.14–0.17 0.5–0.55	100–115	Visean
T. vulgaris Malakhova (1956)	=/*n* BA/*x*	0.40–0.57 0.20–0.25	110	Visean

* shows those species that ought to be reexamined. Unfortunately, the author can not refer to the following five species: *Tetrataxis barkhatovae* Glozdilova and Levedeva (1960), *T. dievi* Malakhova (1956), *T. maxima* var. *depressa* Schellwien (1898), *T. nemejci* Vasicek and Ruziska (1957), and *T. zelleri* Petri (1956).

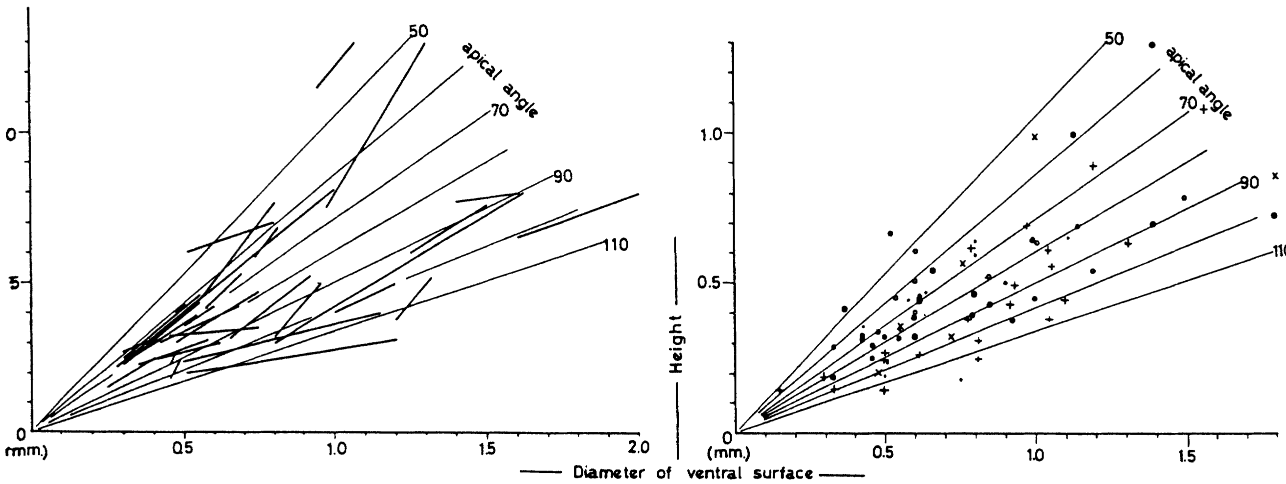

Fig. 2. Width-Height-Apical angle diagrams based on the measurements given in previous works. Note that various lines cross the apical angle line, which shows the species defined on the basis of oblique sections. Dots, Tournaisian species; circles, Visean species; crosses, Upper Carboniferous species; and ×, Permian species.

in the axial (∞/*n*/∞) and horizontal (∞/∞/90°) sections. The number of chambers per whorl is countable in a section oriented horizontally or nearly so, and the morphological nature in early stages can not be completely observed in oblique section.

However, in previous studies all the species are described and illustrated on the basis of nearly axial or parallel sections except for a few species examined with the use of loose specimens. Therefore, it may safely be said that true shell sizes and apical angles of many taxa have never been measured.

The measurements of all the species of *Tetrataxis*, which the present author could examine, are collectively shown in Table 1. The author follows Cummings' thin-section analytical method (1958) for the orientation (section). We have to notice that width/height ratios are not closely related with apical angles in many species (Fig. 2). This fact indicates clearly the morphology described on the basis of incomplete thin sections. As shown in this table, about 40 percent of the species ought to be re-examined by making properly oriented thin sections.

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