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LATE PERMIAN TETHYAN CONODONTS FROM WEST TEXAS AND THEIR SIGNIFICANCE FOR WORLD-WIDE CORRELATION OF THE GUADALUPIAN-DZHULFIAN BOUNDARY

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With 21 figures

Abstract:
With the discovery of Tethyan Late Permian conodonts in the uppermost Altuda Formation, a direct correlation of the lower part of the Tethyan Late Permian (Dzhulfian) with the 'latest Capitanian' in the Glass Mountains, West Texas is possible. In the Glass Mts. there is a major overlap of the 'Capitanian' with the Dzhulfian (or Wuchiapingian) Stage. In agreement with the historic definition, the top of the Guadalupian Series (= top of the Capitanian Stage) can now be defined with the transition from *Mesogondolella 'babcocki'* (guideform of most of the Lamar Limestone, uppermost unit of type Guadalupian Series) to *Clarkina cf. changxingensis* within a phylomorphogenetic continuum. The now clarified relation between the Guadalupian Series and the Tethyan Late Permian removes the last obstacle for using the Guadalupian Series (comprised of Roadian, Wordian and Capitanian stages, in ascending order) as an international reference for the Middle Permian.

Zusammenfassung:
Die Entdeckung tethyaler oberpermischer Conodonten in der obersten Altuda-Formation ermöglicht eine direkte Korrelation des unteren tethyalen Oberperm (Dzhulfian) mit dem „obersten Capitanian" der Glass mts., West-Texas. In den Glass mts. gibt es eine beträchtliche Überlappung des dortigen „Capitanian" mit dem tethyalen Dzhulfian (oder Wuchiapingian). Die Obergrenze der Guadalupe-Serie (= Obergrenze des Capitanian) kann nun, in Übereinstimmung mit der historischen Definition in den Guadalupe Mts., mit dem kontinuierlichen phylomorphogenetischen Übergang von *Mesogondolella „babcocki"* (Leitform des größten Teils des Lamar-Kalksteins, der obersten lithostratigraphischen Einheit des Guadalupian in dessen Typusregion) zu *Clarkina* cf. *changxingensis* definiert werden. Die nun geklärte Beziehung zwischen der Guadalupe-Serie und dem tethyalen Oberperm beseitigt das letzte Hindernis für die Verwendung der Guadalupe-Serie (vom Liegenden zum Hangenden mit den Stufen Roadian, Wordian und Capitanian) als internationaler Standard.

Introduction

The Middle Permian of the Delaware Basin and its margins, well exposed in the Guadalupe Mts. and Glass Mts. (fig. 1), is rich in pelagic and shallow-water fossils that have been studied for about 100 years and described in numerous monographs since GIRTY (1908). The lateral transitions between backreef, reef, forereef, and basinal deposits are well known and the different lithofacies and sequence relationships of these Middle Permian rocks are according to GLENISTER et al. (1991) better studied than in any other Middle Permian area.

However, a main correlation problem is that the upper boundary of the Guadalupian Series (= upper boundary of the Capitanian Stage) could not be correlated exactly with the Tethyan scale. This has discouraged general use of the Guadalupian Series and its stages as an international standard, despite the clear advantage of these terms in comparison with other chronostratigraphic terms for the Middle Permian. The discovery of Tethyan Late Permian conodonts in West Texas above latest Guadalupian conodont faunas now allows an exact correlation of the latest Guadalupian (latest Capitanian) with the Tethyan scale.

Conodont faunas of the latest Guadalupian of the Glass Mts. and their ages

The investigated section (locality 2.3 of the Guidebook to the Guadalupian Symposium, Sul Ross University, Alpine, Texas, March 1991) ist situated NW of Old Blue Mountain in the western Glass Mts., about 1 km S of the Es-

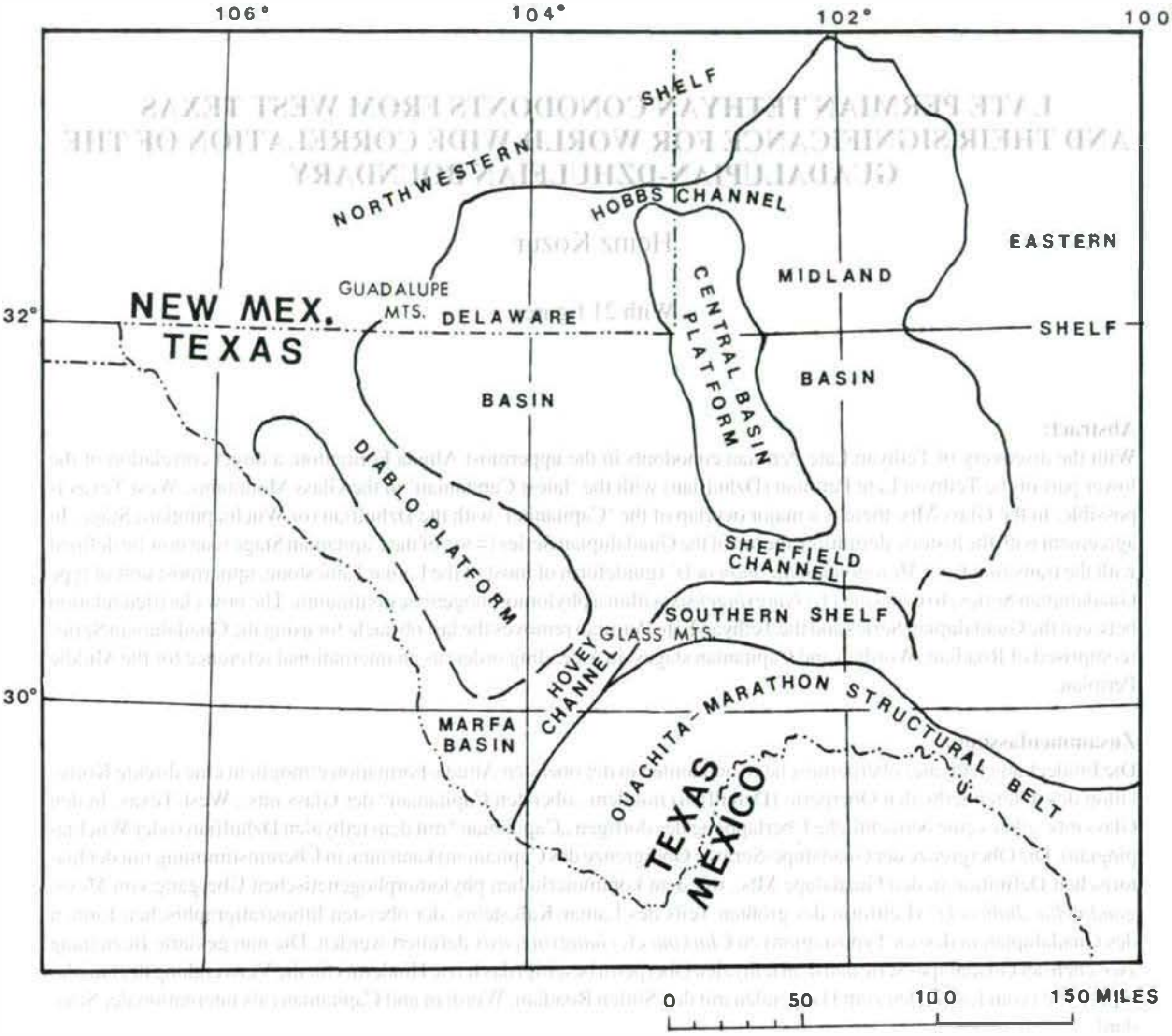

Fig. 1: Paleogeographic position of the Delaware Basin, West Texas. Slightly changed after Oriel et al. (1967).

terwood Ranch (for exact location see ROHR et al., 1991, fig. 25). Additionally one sample (# 154) was investigated from a small outcrop opposite locality 2.2 of the Guadalupian Symposium, situated about 1 km W of locality 2.3. It was taken from the uppermost Altuda Fm., 10–20 cm below the base of the overlying Tessey Fm. The stratigraphic position of the investigated samples of locality 2.3 is indicated in fig. 2; their conodont content is shown in fig. 3.

Before discussing the age of the conodont faunas, an important link between the Middle Permian species of the *Mesogondolella postserrata* group and the Tethyan Late Permian and Early Triassic genus *Clarkina* KOZUR is discussed.

Clarkina changxingensis (WANG & WANG)[1]

(Figs. 9–12, 14–17)

Material: 53 specimens. Figured material housed at the Museum of Northern Arizona; other material housed at the Geol. Inst. of Innsbruck Univ., Austria.

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[1] According to a pers. comm. from Dr. B. WARDLAW, Reston, Va., this form is identical with a 'new species of *Mesogondolella*' that he wishes to describe. Therefore this form is not named. It belongs to *C. changxingensis*, but is perhaps a new subspecies.

Occurrence: Frequent in the uppermost 7 m of the Altuda Fm. of the western Glass Mts.; rare in the Dzhulfian of Transcaucasia and in the Wuchiapingian of South China (unpublished material of the author). ? Dzhulfian of western Sicily.

Remarks: *Clarkina cf. changxingensis* (WANG & WANG) evolved in a phylomorphogenetic continuum from *Mesogondolella 'babcocki'* (CLARK & BEHNKEN). The latter is a new species (*Mesogondolella* n. sp. A, figs. 4–6) of the *M. postserrata* group. It is not described here, because WARDLAW mentioned in his lecture in Alpine (March, 1991) the presence of a *Mesogondolella* n. sp. in the uppermost Altuda Fm. that may be identical with the present form (the only recognized new *Mesogondolella* species in the investigated material).[2] Because *Mesogondolella* n. sp. A has been included in '*Neogondolella*' *babcocki* by CLARK & BEHNKEN (1979), it is designated here as *M. 'babcocki'*. The holotype of '*N.*' *babcocki* (CLARK & BEHNKEN, 1979) is inseparable from *M. postserrata* (BEHNKEN, 1975) and '*N.*' *babcocki* s. str. is therefore a junior synonym of the latter species (WARDLAW et al., 1990; ROHR et al., 1991).

The transition from *M. 'babcocki'* to *C.* cf. *changxingensis* is characterized by the following changes: The highly upturned and narrow lateral platform margins of the former species became broader and flat; the serrations of the anterior platform disappeared in all specimens; the terminal cusp disappeared (still present in transitional forms); the keel became broader, totally flat or even higher in the central part than in the marginal part.

Clarkina ? wilcoxi (CLARK & BEHNKEN) (figs. 7, 8) has a distinct cusp, and subtle serrations of the anterior platform margin are in most specimens present. However, the lateral platform margins are in some specimens (e.g. in the holotype) already broad and flat.

C. cf. *changxingensis* is the forerunner of several Dzhulfian to Changxingian *Clarkina* species: *C. changxingensis changxingensis* (WANG & WANG), *C. deflecta* (WANG & WANG), *C. sosioensis* GULLO & KOZUR, and *C. subcarinata* (SWEET). Tansitional forms to these species are known from the uppermost Altuda Fm. and partly also from western Sicily.

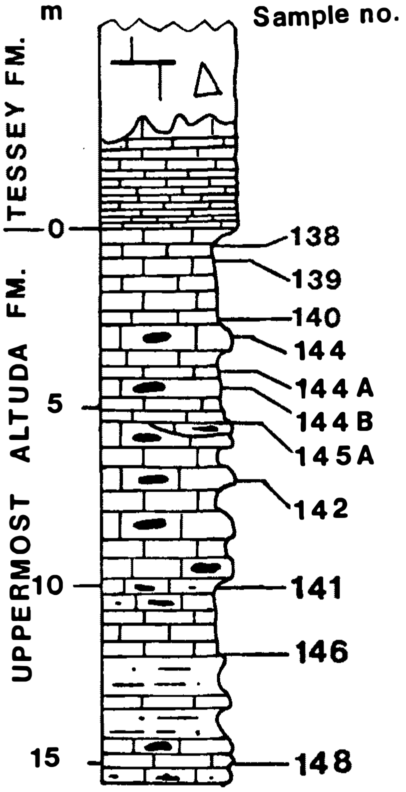

Fig. 2: Section in the uppermost 15 m of the Altuda Fm. and basal Tessey Fm. of locality 2.3 after ROHR et al. (1991).

Two distinct conodont faunas are present in the upper 15 m of the Altuda Fm. of locality 2.3 (see fig. 3). The older association, present also in further samples taken about 5 m below the section, is characterized by *M. 'babcocki'*. The younger association is dominated by *C.* cf. *changxingensis; Hindeodus typicalis* (usually transitional forms to *H. julfensis*), *Clarkina changxingensis changxingensis* and transitional forms from *C.* cf. *changxingensis* to *C. sosioensis* (*Clarkina* n. sp., fig. 13) and to *C. subcarinata* (*C. cf. subcarinata*, fig. 21) are sporadically present. The lower part of the stratigraphically younger unit also yielded *C. ? wilcoxi , and M. 'babcocki'* is still present. *H. julfensis* s. str. and *Clarkina rosenkrantzi* are rarely present in the upper part of the upper faunal unit. *C. lanceolata* (DING) was found in the uppermost 20 cm of the Altuda Fm. near locality 2.2 of the Guadalupian Symposium.

A Late Dzhulfian age is indicated for the upper 4 m of the Altuda Fm. by the presence of *H. julfensis* s. str. (with a smooth hump on the posterior blade). Such forms are usually restricted to the Changxingian (Abadeh and Julfa, Iran; Soviet Transcaucasia; South China; western Sicily), but first, rare specimens with smooth hump appear in the Late Dzhulfian of Greece (NESTELL & WARD-

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[2] According to a pers. comm. from Dr. B. WARDLAW, this form is not identical with a '*Mesogondolella* n. sp.' (see footnote 1). it will be described by KOZUR & MOSTLER (in prep.) as *Mesogondolella ultima*.

Sample no. (m below the Tessey Fm.)	1	2	3	4	5	6	7	8	9	10	11
154 (0.10–0.20 m)			x				x				
138 (0.50 m)			x								
139 (0.80 m)			x								
140 A (2.50 m)			x	x		x			x	x	
144 (3.00 m)	R	x	x		x	x				x	
144 A (4.00 m)			x	x		x		x			
144 B (4.50 m)			x								
145 (5.00 m)			x								
145 A (5.50 m)	x		x	x					x	x	x
142 (7.00 m)	x	x	x								
143 (9.00 m)	x	x	x		x				?		
141 (10.0 m)	x	x	cf.								
146 (12.0 m)	x										
148 (15.0 m)	x										

Fig. 3: Conodont distribution in the upper 15 m of the Altuda Fm. of locality 2.3. Sample 154 is derived from an outcrop opposite locality 2.2.
1 = *M. 'babcocki'* (CLARK & BEHNKEN), 2 = *Clarkina ? wilcoxi* (CLARK & BEHNKEN), 3 = *C.* cf. *changxingensis*, 4 = transitional forms between *C.* f. *changxingensis* and *C. subcarinata* (SWEET), 5 = *C. changxingensis changxingensis* (WANG & WANG), 6 = *C. rosenkrantzi* (BENDER & STOPPEL), 7 = *C.* aff. *subcarinata* (SWEET), 8 = *Hindeodus julfensis* (SWEET), 9 = *H. typicalis* (SWEET), 10 = *Clarkina* n. sp., 11 = *Stepanovites dobruskinae* KOZUR & MOVSOVIC, R = reworked specimens.

LAW, 1987, fig. 4.9). The age of *H. julfensis* s. str. in the uppermost Altuda Fm. is, like in Greece, Late Dzhulfian, because typical representatives of *C. subcarinata* are still missing, whereas its forerunner (fig. 21) is present. This age is also indicated by the presence of *Clarkina Lanceolata* (DING) in the uppermost 20 cm of the Altuda Fm. Such forms have been placed so far in *S. subcarinata* (partly as independent subspecies), a Changxingian guideform. However, recent studies of Chinese material has shown that these forms belong to an independent Late Dzhulfian species. These forms may be juvenile specimens of *C.* cf. *changxingensis.*

The lower part of the upper faunal unit with *C.* cf. *changxingensis, C. wilcoxi* and *M. 'babcocki'* belongs to the Early Dzhulfian. The first species is unknown from pre-Dzhulfian beds. *C. wilcoxi* is mostly restricted to the Dzhulfian, but occurs already in transitional beds between the Dzhulfian and the 'Midian'. *M. 'babcocki'* is restricted to the Dzhulfian s.l. (including the *Lepidolina kumaensis* fusulinid fauna). However, the *L. kumaensis* Zone is older than the Transcaucasian type Dzhulfian and placed there in the 'Midian' (= Abadehian, both stages are junior synonyms of the Capitanian). If we use the lower boundary of the type Dzhulfian in its Soviet Transcaucasia stratotype then *M. 'babcocki'* is a pre-Dzhulfian (s. str.) fossil.

Correlation of the upper boundary of the Guadalupian Series (= upper boundary of Capitanian stage) with the Tethyan standard

As shown by the above conodont data, the uppermost Altuda Fm. of the western Glass Mts. comprises the Dzhulfian indicating a major overlap of the 'Guadalupian' and the Tethyan Late Permian in this area. However, the latest Guadalupian Series and the latest Capitanian Stage are defined in the Guadalupe Mts. by the Lamar Ls. fauna of the Guadalupe Mts. (type area of both the Guadalupian and the Capitanian). Late Permian conodont faunas of the Glass Mts. are clearly younger than the conodont faunas of the Lamar Ls. because they succeed the *M. 'babcocki'* fauna (characteristic for most of the Lamar Ls.) in a phylomorphogenetic continuum. Only in the uppermost few centimeters of the Lamar Ls., Dzhulfian conodonts and radiolarian faunas, e.g. *C.* cf. *changxingensis*, highly evolved *C.* cf. *bitteri* (KOZUR), *Follicucullus ventricosus* ORMISTON & BABCOCK and *Ishigaconus scholasticus* (ORMISTON & BABCOCK) are present.

Correlation of the Lamar Ls. (*Mesogondolella 'babcocki'* fauna) with the Tethyan succession is still in dispute. However, at least the lower part of the Lamar, which contains the Tethyan fusulinid *Yabeina*, is older than the Tethyan Late Permian.

FURNISH (1973) regarded the Lamar Ls. on the basis of its ammonoid fauna as post-Guadalupian, but pre-Dzhulfian. This Amarassian (or Abadehian) Stage was used by many authors (including the present author), but its separation from the Capitanian was doubtful (KOZUR, 1977). Whereas these authors assumed the presence of a stage between the Capitanian and Dzhulfian stages, ZUREN et al. (1989, p. 282) stated that the 'Dzhulfian Stage in Transcaucasia and the Changxingian stage in South China represent the overlap of at least part of the Capitanian of North America'.

GLENISTER et al. (1991, p. 14, presented summary evidence that '...the Dzhulfian succeeds the Guadalupian without major overlap or omission', based on correlation through the '... post-Capitanian La Colorada beds at the top of the Las Delicias section (SPINOSA, FURNISH and GLENISTER, 1970)' of Coahuila, Mexico. They noted the similarity of the *Eoaraxoceras* ammonoid fauna of the La Colorada beds to that of the '... (basal one-half of the *Araxoceras* beds of TARAZ, 1971) at Abadeh in central Iran' which in turn was correlated with the '...basal type Dzhulfian'. However, araxoceratids have been reported from the *Araxilevis* beds, beneath the *Araxoceras* beds, in both the Abadeh area and the type Dzhulfian, and several levels for the lower boundary of the Dzhulfian are in current use (KOTLJAR et al., 1989). Under some definitions, the *Eoaraxoceras* fauna of Coahuila corresponds to the 'middle' part of the Tethyan type Dzhulfian. Moreover, the *Eoaraxoceras* fauna of the upper La Colorada beds (upper bed 1 of KING et al., 1944) lies several 100 m above the upper Capitanian ammonoid- and fusulinid faunas of bed 2 of KING et al (1944). So, the ammonoid data can be interpreted to indicate only that the 'middle' Dzhulfian is younger than the upper Capitanian.

More detailed correlations of the Lamar Ls. are possible with the aid of microfaunas. The basal Lamar Ls. with the Tethyan fusulinid *Yabeina* is surely pre-Dzhulfian. The upper Lamar Ls. with the *Reichelina lamarensis* fauna (WILDE, 1955, 1990) and without larger fusulinids could be Dzhulfian in age. The radiolarian fauna of the uppermost Lamar Ls. with *Follicucullus ventricosus* ORMISTON & BABCOCK and *Ishigaconus scholasticus* (ORMISTION & BABCOCK) indicates according to KOZUR (in press) an earliest Dzhulfian age near the Capitanian-Dzhulfian boundary. It contains *C.* cf. *changxingensis* and highly evolved *C.* cf. *bitteri* indicating Dzhulfian age and it is underlain by *M. 'babcocki'* conodont fauna. In Japan, this radiolarian fauna lies above the *Lepidolina kumaensis* fusulinid fauna.

Mesogondolella 'babcocki' has been recorded from the definitely pre-Dzhulfian (pre-Wuchiapingian) upper Maokou Fm. of South China, which is overlain by the Wuchiaping Formation with Dzhulfian (Wuchiapingian) ammonoids and brachiopods. Therefore at least the lower *M. 'babcocki'* fauna of the lower Lamar Ls. must be pre-Dzhulfian in age, and this is in agreement with the above fusulinid data. *Clarkina ? wilcoxi* has been also reported from the uppermost Maokou Fm. This species begins in the Glass Mts. immediately before the first appearence of typical *C.* cf. *changxingensis*. The lower 60 m of the Dzhulfian (Wuchiapingian) Wuchiaping Fm. from South China are characterized by highly evolved *Clarkina bitteri* (Kozur) and *Clarkina liangshanensis* (WANG & WANG). Above this level, *Clarkina leveni* (KOZUR et al.) is present. The *C. leveni* Zone corresponds to the upper part of the lower and to the middle type Dzhulfian and roughly to beds with the *Eoaraxoceras* ammonoid fauna in Mexico. Using the above conodont data, the transition from *M. 'babcocki'* to *C.* cf. *changxingensis* lies either directly at the base of the type Dzhulfian or within the Early Dzhulfian.

The top of the Middle Permian Guadalupian Series (= top of the Capitanian Stage) is therefore here defined by the transition from *M. 'babcocki'* to *C.* cf. *changxingensis* within a phylomorphogenetic continuum discovered in the uppermost Altuda Fm. of the western Glass Mts. In agreement with the original definition, the fauna of the Lamar Ls. (with exception of its uppermost centimeters with Early Dzhulfian conodont and radiolarian faunas, KOZUR, in press) is regarded as the topmost Guadalupian (topmost Capitanian) fauna that is immediately succeeded by type Dzhulfian faunas.

If the Dzhulfian (or Wuchiapingian) base will be defined in future with the base of the Wuchiapingian in South China, then the *Lepidolina kumaensis* Zone (older than the type Dzhulfian in Soviet Transcaucasia) will be included in the Dzhulfian (or Wuchiapingian). This boundary lies in a lower horizon within the Lamar Ls., immediately above the *Yabeina lamarensis* fauna of the lower Lamar Ls. Also in this case, the base of the Tethyan Dzhulfian (or Wuchiapingian) can be well correlated with a horizon inside the uppermost type Capitanian Lamar Ls. by fusulinids (top of the *Yabeina lamarensis* fauna), conodonts (apppearence of the *Mesogondolella 'babcockae'*[3] – *Hindeodus* n. sp. fauna) and radiolarians (appearence of the *Follicucullus transitus* fauna). The problem of the cor-

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[3] *M. 'babcockae'* begins somewhat earlier or the Maokou-Wuchiaping boundary is diachronous.

relation of the type Capitanian upper boundary with the Tethyan scale is therefore solved, independent from the final definition of the base of the Tethyan Dzhulfian.

Conclusion

There is a major overlap between strata referred previously to the Guadalupian Series of the Glass Mts. and the Tethyan Late Permian. The Dzhulfian is present in the uppermost Altuda Fm. These beds have so far been included in the Late Capitanian (latest Guadalupian), but have to be excluded from this stage.

Below the definitive Late Permian Tethyan conodont faunas of the Glass Mts., the *M. 'babcocki'* fauna is present, which correlates with the *M. 'babcocki'* fauna of the Lamar Ls. (faunistically latest Guadalupian of the Guadalupe Mts.). There is a gradual transition between *M. "babcocki"* and *C.* cf. *changxingensis* in a phylomorphogenetic continuum that is used to define the top of the Capitanian Stage (and of the Guadalupian Series). This transition lies either at the base of the Tethyan type Dzhulfian or within the Early Dzhulfian.

The Guadalupian can be now defined, at both its lower and upper boundaries, by distinct faunal changes within phylomorphogenetic continua: *M. idahoensis – M. nankingensis*[4] at its lower boundary and *M. 'babcocki'* – *C.* cf. *changxingensis* at its upper boundary. Both these lineages represents conodonts that are also present in the Eurasiatic Tethys and partly also in the Boreal realm (KOZUR, 1977, 1978; KOZUR & NASSICHUK, 1977). In the Boreal realm, the development of *C. rosenkrantzi* (BENDER & STOPPEL) from *Mesogondolella ? behnkeni* (BANDO et al.) of the *M. postserrata* group, and the first appearence of *Merrillina divergens* (BENDER & STOPPEL) can be used for the definition of the Capitanian/Dzhulfian boundary. Unlike the fusulinid-based Tethyan scale, the Guadalupian and its stages can be recognized world-wide. This favors the use of the Guadalupian and its stages (Roadian, Wordian, Capitanian) as the international reference for the Middle Permian.

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[4] In spring 1991 rich material of *M. serrata* CLARK & ETHINGTON, 1962, from the Guadalupe Mts. was studied. In September 1991 topotype material of *M. nankingensis* CHING, 1960, was studied in Nanjing (together with Prof. WANG, CHENG-YUAN). According to our opinion M. serrata is a junior synonym of *M. nankingensis*.

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Explanation of figures 4–21 (see page 186)

Conodonts from locality 2.3 and from the outcrop opposite locality 2.2 (only fig. 18), magnifications 100 x, except fig. 13 (50 x); specimens housed in the geology collection of the Museum of Northern Arizona, Flagstaff;

Figs. 4–6: *Mesogondolella 'babcocki'* (CLARK & BEHNKEN). Fig. 4: upper view, sample 146, latest Capitanian, rep.-no. N 4048. Figs. 5, 6: reworked specimens, upper views, sample 144, Dzhulfian, rep.-no. N 4042 and N 4043.

Figs. 7, 8: *Clarkina rosenkrantzi* (BENDER & STOPPEL), sample 144, Dzhulfian.
Fig. 7: lower view, rep.-no. N 4044, fig. 8: upper view, rep.-no. N 4040.

Figs. 9-12,
14–17: *C.* cf. *changxingensis.*

Figs. 9, 11: oblique upper view, sample 145 A, Dzhulfian, rep.-no. N 4014. Fig. 10: upper view, sample 145 A, Dzhulfian, rep.-no. N 4019. Fig. 12: upper view, sample 144 A, Dzhulfian, rep.-no. N 4023. Fig. 14: upper view, sample 144 A, Dzhulfian, rep.-no. N 4022. Fig. 15: upper view, sample 140 A, Dzhulfian, rep.-no. N 4031. Fig. 16: lower view, sample 140 A, Dzhulfian, rep.-no. 4028. Fig. 17: upper view, sample 140 A, Dzhulfian, rep.-no. N 4035.

Fig. 13: *Clarkina* n. sp., transitional form between *C.* cf. *changxingensis* and *C. sosioensis* GULLO & KOZUR, upper view, sample 144, Dzhulfian, rep.-no. N 4041.

Fig. 18: *C. lanceolata* (DING), upper view, sample 154, Late Dzhulfian, rep.-no. N 4037.

Fig. 19: *Hindeodus typicalis* (SWEET), sample 145 A, Dzhulfian, rep.-no. N 4020.

Fig. 20: *H. julfensis* (SWEET), sample 144 A, Dzhulfian, rep.-no. N 4021.

Fig. 21: *C.* cf. *subcarinata* (SWEET), upper view, sample 144 A, Dzhulfian, rep.-no. N 4024.

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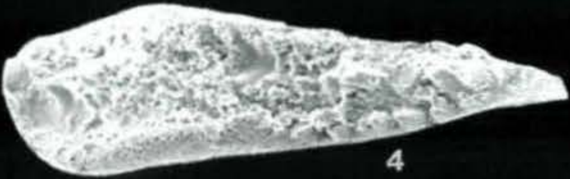
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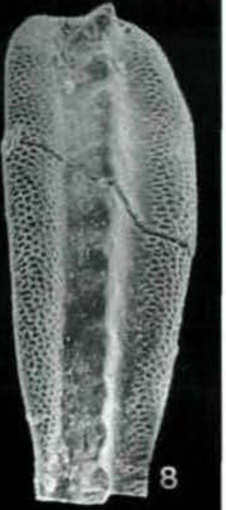
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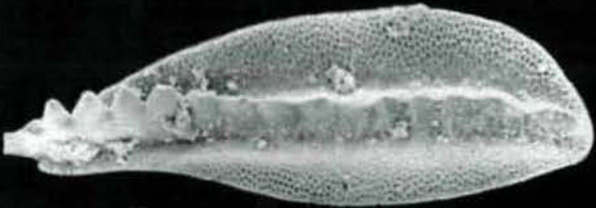
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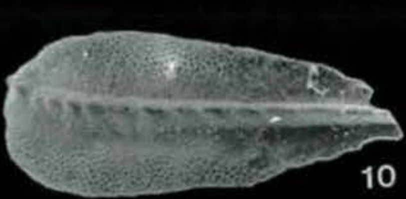
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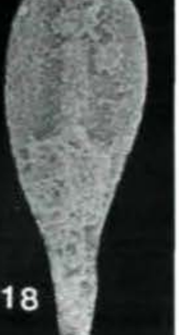
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