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Correlation of Tectono-Stratigraphic Units in Northern Thailand with Those of Western Yunnan (China) *

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ABSTRACT

A tentative correlation scheme for the tectono-stratigraphic units of Northern Thailand and those of Western Yunnan (China) is proposed. We point out that a correlation between the Changning-Menglian belt in Western Yunnan and the Nan-Uttaradit zone in Northern Thailand (or and a "cryptic suture" in the Chiang Rai-Chiang Mai region) is unlikely, for it would demand a "suture" which cuts across a zone with high-grade metamorphics and granite intrusions (Doi Inthanon-Lincang unit). Therefore, the northern continuation of the Lampang region is situated in the Simao region of Yunnan, as indicated by a very similar development during Permian and Triassic (Lampang-Yunxian unit). The Nan-Uttaradit zone is considered to be the easternmost part of this unit, and its northern continuation should be traceable via Luang Prabang in Laos into the southeastern parts of the Simao basin. Here, however, outcrops of this unit have not yet been found. The same is the case with the Phetchabun unit which follows to the east. Both units are probably hidden under a thick cover of Mesozoic red beds. The whole region was characterized by a highly mobile tectonic development with alternating phases of compressional and extensional deformation.

KEY WORDS correlation, tectono-stratigraphic, compressional and extensional deformation.

The correlation of tectono-stratigraphic units of Northern Thailand with those of Western Yunnan (China) is still little understood, partly because of the paucity of geological data from the Union of Myanmar and the Laos, and partly due to the conflicting geodynamic concepts adopted by various authors during the past few decades.

In this contribution, we describe a tentative correlation scheme which is based on our extensive fieldwork in both regions on detailed stratigraphic and paleontological studies and on a new, independent geodynamic concept. In order to avoid confusion, often used nomenclature, such as "Shan-Thai craton" or "Sukhothai foldbelt", is avoided and preliminary, unof-

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ficial names are preferred instead.

Even small scale geotectonic maps of mainland SE-Asia and adjacent parts of China show clearly that Northern Thailand as well as Western Yunnan are built up by mountain ranges, generally striking N-S. In the first place, we choose a unit which has much in common in both countries and can most easily be followed through parts of the Union of Myanmar and Laos. This unit is characterized by high-grade metamorphic rocks and will be used as the "backbone (key?)" for further correlations.

DOI INTHANON-LINCANG UNIT

In Northern Thailand, west of the Chiang Mai basin and west of the Lancangjiang in Western Yunnan, high-grade metamorphics with multiple granite intrusions (of Permian and Triassic in Yunnan and Triassic in Thailand) are widely exposed. Formerly, this complex was regarded as "Precambrian", but extended isotopic age—dating as well as structural studies—revealed a much more complicated geodynamic history, at least for the Thai part. Based on these new data, the high-grade metamorphics were discussed either in the context of extended alpine-type. Tertiary nappe tectonics or as "metamorphic core complexes" (Macdonald et al., 1993) caused by late orogenic extension and uplift, like those known from the North American Cordillera (Crittenden et al., 1980). The second interpretation is favoured here.

For the Yunnan part of the Doi Inthanon-Lincang unit, the interpretation of the nature of the Lincang granite and associated high-grade metamorphics is apparently behind by some years: the "paleogeographic Atlas of Yunnan" (Wang, 1995) shows this region from Sinian till Triassic as "Lincang old land", i. e. as an island during the whole Paleozoic.

Our investigations on the core/cover relations of the Lincang complex favour strongly a re-interpretation of this region. Extensive mylonites are mapped, especially along the eastern side of the Lincang complex, and in some areas granitic intrusions and metamorphics are overlain by Middle Jurassic clastics. Contrary to the information presented on Chinese maps, this contact is—at least in the few localities we tested—of a tectonic nature.

In Thailand, the cover sequences generally show only a slight metamorphic overprint and are composed of sediments ranging from (? Cambrian) Ordovician to Permian. Triassic strata are only known locally (Lüning, 1994), and Jurassic red beds were probably deposited in local graben structures (Lüning et al., 1995).

Paleozoic sedimentary sequences developed in this region are still little understood, since they comprise sediment-assemblages which are not usually expected in such close relationship one to another. For example: the morphology of the region between Mae Hong Son and Pai is characterized by a typical karst topography and the data by Toriyama (1984, 1944), Konishi (1953) and Fontaine et al. (1993) show that during most of Carboniferous and Permian, a shallow carbonate platform existed in this region, which was situated in tropical to subtropical latitudes. However, from the same region, thick siliciclastic strata of Carboniferous are known (Fujikawa and Ishibashi, 2000). These siliciclastics are quartz-rich and mature. Furthermore, ribbon cherts with upper Paleozoic through Middle Triassic radiolaria (Lüning, 1994) have been mapped. We interpret these observations as indication that these regions were part of a disrupted passive continental margin during Upper Paleozoic times (at least till the upper Middle Permian), only during the Triassic did this scenario change and some immature clastics were deposited (Töfke et al., 1993). Similar observations were described from the region of Chiang Dao (Caridroit, 1993) and are also known from SW Yunnan. The most famous one of these regions in SW Yunnan, the Changning-Menglian tectonic belt, is interpreted by most Chinese scientists (including Feng Q) as the main branch of the Paleotethys, which was located next to the disrupted passive continental margin.

Available geological maps from the Union of Myanmar and Laos make it quite apparent that this zone with "metamorphic core complexes" can be traced from Northern Thailand through Myanmar (region of Kentung) and westernmost Laos into Southwestern Yunnan. Therefore, other major pre-Tertiary structures (such as "sutures") presumably cannot cross this belt (Metcalfe, 1999; Zhong, 1999). Geological features, which in Yunnan are west and east of this belt, should also be found in Northern Thailand, west and east, respectively, of this belt.

LAMPANG-YUNXIAN UNIT

East of the quite well-defined Doi Inthanon-Lincang unit, another unit, can be outlined, which is rather difficult to recognize since it is largely (especially in Yunnan) buried under a thick cover of Mesozoic—Eocene red beds. On Thai territory, this unit is almost identical to the "Sukhothai foldbelt". Characteristics of this belt are the following geological features.

(1) Phyllitic sequences. The age of the phyllites is generally not proven by isotopic data, but according to regional arguments, the metamorphism is probably of Middle Permian (or even older?). A Permian (approximately 265 Ma of K/Ar) is confirmed for phyllitic rocks found some kilometres to the west of Phrae (Mickein, 1992). Barr and Macdonald (1987) reported a Permian K-Ar age of (269±12) Ma for actinolite from mafic schists of the Pha Som Group. This age may indicate that a minimum metamorphic age for the metamorphics found close to the Nan-Uttaradit suture. Phyllites related to a younger metamorphic event are known, for example, from the region between the Sirikit Dam and the Nam Pat basin (Ahrendt et al., 1993).

(2) Where the metamorphic overprint is less strong, a gap in the stratigraphic record between the Upper Carboniferous/Lower Permian and the Upper Permian is apparent in many regions. A convincing example that this gap is caused by an orogenic event is known to us only from the region west of Yunxian near Simao, Yunnan, where a regional angular unconformity has been mapped (Feng and Helmcke, in print). In the region of the Kiu Lom reservoir in Lampang, a similar example

of the intra-Permian angular unconformity was discovered by colleagues from Chiang Mai University (oral communication Prof. Sompong Chanmee, 1995).

(3) Extensive intermediate to acidic volcanics and volcaniclastics are known from various regions in this belt. These volcanics are often regarded as remnants of a Permo-Triassic (in Thailand) or Triassic (in Yunnan) volcanic arc, but are interpreted in this paper as late to post-orogenic volcanics related to extension. However, there are indications that in Yunnan Paleozoic volcanics have also been mapped as part of this Triassic sequence.

(4) Extension since the Upper Permian (Ishibashi et al., 1994; Senowbari-Daryan and Ingavat-Helmcke, 1993; Yanagida et al., 1988) also created new depocenters—mainly in the form of half-grabens. In these extensional structures, more or less complete Triassic marine sequences were deposited, which are known in Thailand as the "Lampang Group" (Chaodumrong and Burrett, 1997; Gabel, 1994; Chonglakmani, 1983; Pyiasin, 1971). Though many details are still unresolved, it is clear that not one large basin existed during Triassic in Northern Thailand, but three or four small basins characterized by different stratigraphic sequences. The stratigraphic record is most complete in the western part—in the eastern basins, only the upper part of the Triassic is recorded in the sediments.

On Thai territory, the typical section of the Triassic occurs along the Lampang-Ngao highway. Here, the sudden change from shallow marine limestones (Anisian) to mainly turbiditic clastics (Hong Hoi Formation of the Ladinian) is impressive, and a strong argument in favour of an extensional setting (Gabel, 1994; Helmcke, 1983), and against the interpretation of the Hong Hoi Formation as "flysch".

A very similar development can be observed in parts of the Simao basin in Yunnan (e. g. Yunxian anticline, NW of Simao). This leaves little doubt that the two successions should be placed in the same unit.

The western boundary of the Lampang-Yunxian unit is often strongly overprinted by the Tertiary uplift of the metamorphic core complexes, and strike slip faults. It is therefore difficult to trace it in the field. Along a line which can be traced from Jinghong in southwestern Yunnan via Fang and Chiang Mai to the south, a number of outcrops are known, which show Upper Paleozoic or Triassic radiolarian cherts (Feng et al., 2001; Sashida et al., 1994; Caridroit, 1993); these occurrences are difficult to interpret at present; in this paper these outcrops are included in the cover sequences of the Doi Inthanon-Lincang unit, however, they are most probably dislocated.

Tentatively we place the eastern boundary of this belt to the east of the "Nan-Uttaradit suture zone", for chromium-spinel grains discovered by Chutakositkanon et al. (1997) in the clastics of the Nam Duk Formation indicate that this region was already subjected to erosion during the upper Middle Permian. Still problematic is the interpretation of Permian (or Permian to Lower Triassic) volcanics, as best known from the region of Phichit.

The "missing link" between sections in Northern Thailand and Southwestern Yunnan must be sought in the northwest of Laos. Some hints are contained in the annotations to the geological map 1 : 1 000 000 of Cambodia, Laos and Vietnam (Phan et al., 1991): the Namtha and the Luong Phabang (Luang Prabang) belts in NW Laos are the most likely candidates. Whilst the Luong Phabang belt is described as composed of folded "eugeosynclinal" sequences (prolongation of the Uttaradit ophiolites), the "miogeosynclinal" Namtha zone is composed mainly of Permo-Triassic terrigenous formations and minor intermediate volcanics. However, in Southwestern Yunnan, up to now no outcrops have been found, which can be interpreted as the northern continuation of the ophiolite belt of Nan-Uttaradit in Thailand, and which should continue, via the Luong Phabang belt, further NE towards the boundary between Laos and Yunnan. A thick sequence of red beds (Jurassic to Eocene), covering most of those parts of Yunnan, where the ophiolites are to be expected, may explain why the search has not been successful. These red beds are interpreted by Yano et al. (1994) as deposited in a continental backarc basin.

Interpretation of LANDSAT-images supports our reconstructions: a predominant SWS-NEN strike direction is evident for this region in Laos.

PHETCHABUN UNIT

In Thailand, east of the Lampang-Yunxian unit follows a unit, which is discussed here under the preliminary name "Phetchabun unit". Until now it has not been possible to discover the equivalents of this unit in Southwestern Yunnan. However, the probable continuation of this unit is known in the Jinshajiang belt of Northwestern Yunnan (Feng, 1999). This may be taken as evidence that this unit also exists in Southwestern Yunnan, although possibly deeply buried under a thick cover of Mesozoic to Eocene red beds, or still unidentified south of the Ailaoshan belt. Further detailed research on the stratigraphy of the Ailaoshan belt is necessary.

Characteristics of this unit is a nearly complete Permian sequence known in central Thailand as "Nam Duk Formation" (Chonglakmani and Sattayarak, 1978). The Nam Duk Formation consists of three sequences (Helmcke and Kraikhong, 1982): (1) Lower to lower Middle Permian pre-orogenic sediments characteristic of a rather deep basin. This sequence contains frequent turbidites with volcanic material and allodapic limestones (Meischner, 1964), which could be age-dated (Winkel et al., 1983) by redeposited fusulinids. (2) Upper Middle Permian syn-orogenic siliciclastic turbidites (typical flysch). (3) Upper Middle Permian to lower Upper Permian siliciclastics (Altermann et al., 1983) indicating a shallowing upwards of the basin (molasse strata). The previously mentioned chromium-spinel grains (Chutakositkanon et al., 1997) were found in the transitional zone of the last two units.

Most of the Triassic is missing, and only the Upper Triassic is represented by continental, lacustrine sediments deposited in extensional depocenters.

This unit can be traced to the south into the region of

Muaklek and Pak Chom, where the Pang Asok Formation is the equivalent of the second member of the Nam Duk Formation (Chonglakmani and Helmcke, 2001) and to the north to the Thai-Lao boundary (Altermann, 1989). The geometry and areal extent of this unit is still little understood—possibly because of displacement along a N-S trending strike-slip fault. In the region west of Loei, this unit is also bounded by a fault zone.

LOEI-JIANGCHEN UNIT

East of the "Phetchabun unit" follows another unit, which has long been known from the region east of Loei in northeastern Thailand. This unit could possibly be traced through the Laos into southwestern Yunnan, where we see it exposed around Jiangchen. We use the informal name "Loei-Jiangchen unit" (to avoid using the name 'Mojiang'—a bigger town north of Jiangchen—since this town is also referred to the description of some ophiolites in the Ailaoshan, which probably belong to a different unit). In Northeastern Thailand, the older strata of the Loei-Jiangchen unit are exposed only in a rather small area east of Loei, but thought to form the basement of the Khorat basin.

East of Loei, a Paleozoic sequence is exposed, which is clearly divided into two parts: a more highly deformed and metamorphosed older sequence and a less deformed and much less metamorphosed sequence of Carboniferous and Permian. This indicates compressional deformation around the Devonian/Carboniferous boundary, or during the Lower Carboniferous (Altermann et al., 1983). Whether this orogenic event was followed by extensional deformation during the Carboniferous is still under discussion for the Khorat basin (Mouret, 1994; Kozar, 1992). The data published by Intasopa and Dunn (1994) on the Loei ocean floor tholeiites (361 Ma) indicate that an advanced stage of rifting may already have existed during Late Devonian.

The post-orogenic sequence is usually subdivided into lower and upper clastic strata with an intercalation of mainly Permian shallow marine carbonates. The find of a Paripteris flora in the Loei region (Laveine et al., 1993) is of great importance for paleogeographic reconstructions, since this Carboniferous flora is a clear indicator of the Northern Tethys.

At the top of the Permian, a gap spanning the Lower and Middle Triassic is recorded. Non-marine strata were deposited in half-grabens during an extensional stage, only in the Norian to Rhaetian. After the deposition of these sediments, inversion took place before the sedimentation of the Khorat Group started. At present, it is disputed whether sedimentation of the Khorat red beds had already started during the Jurassic, or only in the Lower Cretaceous.

The gap between Thailand and Yunnan, as created by the regional extent of Laos, broadens eastward. It is therefore more difficult to connect units in Thailand with those exposed in Yunnan. However, in the region south of Mojiang and east of Jiangchen, some correlations may be possible.

South of Mojiang, Lower Carboniferous pillow basalts are known (age controlled by radiolaria and isotopic data as well as by Eostaffela found in intercalated limestones). These basalts may be correlated with the ocean floor tholeiites described by Intasopa and Dunn (1994) from Loei. The Upper Permian sediments in this region are little deformed and lack cleavage. These strata are composed of shallow marine sandstones, shales and warm water carbonates.

In Laos, the Pusilung structure seems to be the southern extension of the area around Jiangchen in Yunnan. The Pusilung structure is bounded by an important fault zone in the east (Dienbien-Khorat strike-slip fault, Phan et al., 1991).

"WESTERN UNITS" (UNITS WEST OF DOI INTHANON-LINCANG UNIT)

Our correlation of tectono-stratigraphic units in Northern Thailand with those in Southwestern Yunnan started with the high-grade metamorphics of the Doi Inthanon-Lincang unit and continued with units further east. Now we return to the starting point and look at regions west of the high-grade metamorphics.

In Northern Thailand, a remarkable change occurs along the valley of the river Mae Yuam in the region of Mae Sariang. Here a late Paleozoic to Triassic sequence is exposed in a narrow belt, which can be clearly subdivided into pre-orogenic ribbon-cherts and pelagic limestones and typical syn-orogenic turbiditic siliciclastics (Töfke et al., 1993). The ribbon cherts reach stratigraphically up into the Middle Triassic, the siliciclastics were deposited during a short period in the Middle Triassic. Therefore, this sequence can be interpreted as sedimentary evidence of the Triassic Indosinian orogeny, possibly caused by the arrival and docking of a Gondwana-derived terrane with the northern Tethyan continental crust. The regions, west of Mae Sariang and around Mae Sot, are interpreted as part of this terrane. Red beds formerly believed to be of Lower Triassic age (map 1 : 250 000, sheet Chiang Mai) are now dated by radiolaria contained in pebbles, as younger than Middle Triassic (probably Jurassic), and are interpreted as an overstep sequence (Caridroit et al., 1993).

From Southwestern Yunnan, a more complicated situation is described: in west of the Lincang belt, the following units are known (from E to W): Changning-Menglian zone, Baoshan block, Nujiang zone and Tengchong block.

The Changning-Menglian zone is characterized by Paleozoic—Triassic deep water sediments and volcanics and is interpreted by most authors (including Feng Q) as a spur of the former "Paleotethys". Shallow, warm-water limestones in this belt are interpreted as deposited on sea-mounts. In this interpretation the Baoshan and Tengchong blocks are discussed as Gondwana-derived terranes. This interpretation is supported by various geological and paleontological arguments—most famous are the "pebbly mudstones" (Dingjiazhai Formation on Baoshan block, Kongshuhe Formation on Tengchong block). However, some authors (including Helmcke D) prefer to include the Baoshan block (or at least its southern part around Zhengkang) in the "non-Gondwana" realm (Wang et al., 1997, Fig. 1) and

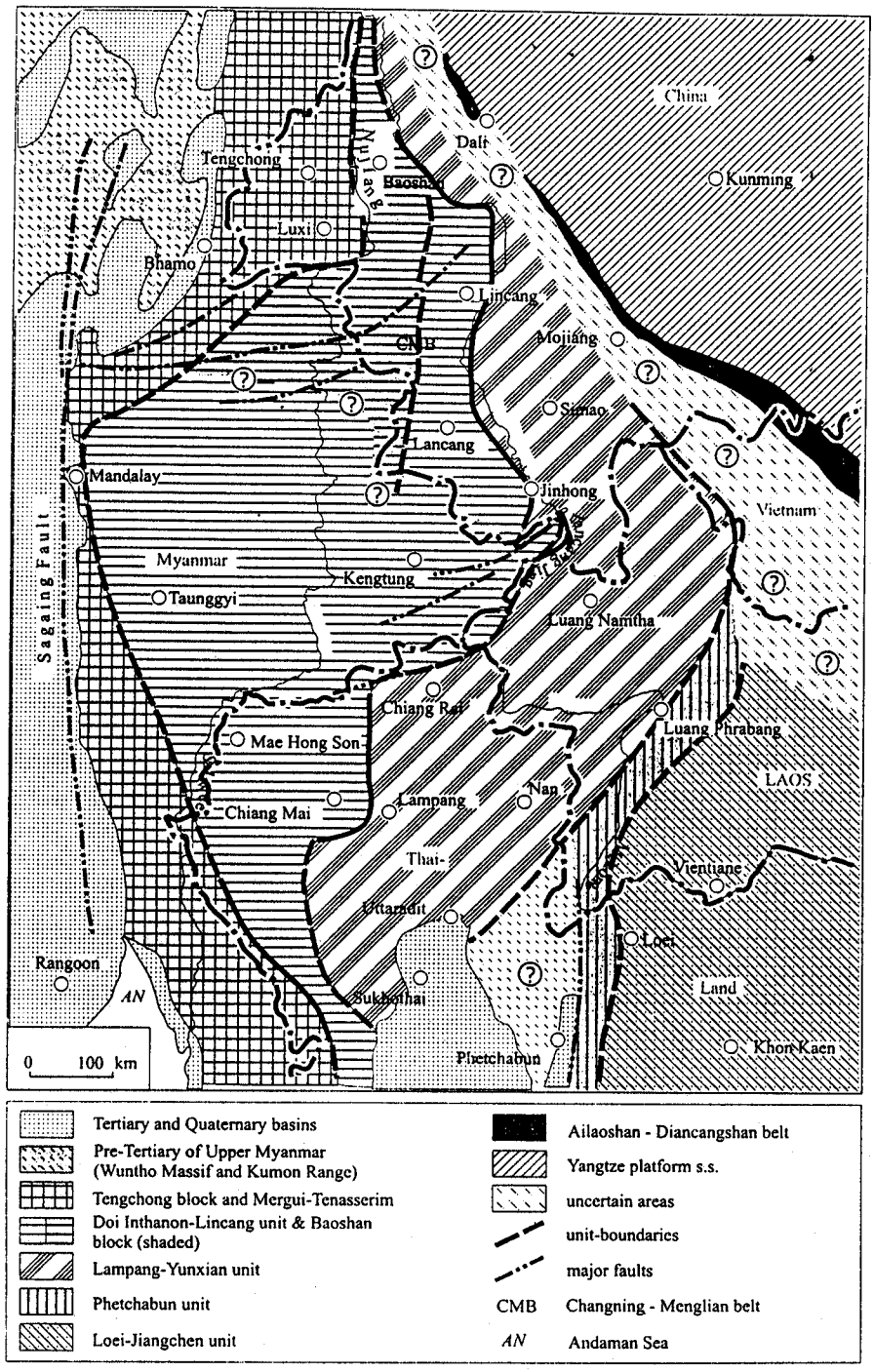

Figure 1. Correlation of tectonic-stratigraphic units of Thailand and Yunnan (China).

to accept only the Tengchong block as a true terrane (main arguments: *Pseudoschwagerina* sp. in the Zhengkang region, Triassic sediments and "ophiolites" between Luxi and Ruili; but comp Ueno, 1999).

However, these discrepant interpretations seem a minor problem at present to us: the results of ongoing and future investigations will resolve this question. More important is the fact that the boundary between the "northern Tethyan realm" and the "probably Gondwana-derived terranes" in Northern Thailand as well as in Southwestern Yunnan is situated clearly in west of the Doi Inthanon-Lincang unit, which is part of the Eurasian (Yangtze plate s. l.) continental crust. Where to trace this boundary through the Union of Myanmar is still little understood and will be treated elsewhere.

CONCLUSIONS

We consider that the correlation of the Changning-Menglian belt in Southwestern Yunnan with the Nan-Uttaradit zone in Northern Thailand (Metcalfe, 1999) is unlikely since it would demand a suture which cuts across a zone of high-grade

metamorphics and granitic intrusions (Doi Inthanon-Lincang unit), which we interpret as the edge of the continental plate. This correlation also avoids placing Lower Permian warm-water carbonates, which have been known in Northern Thailand for a long time (Fontaine et al., 1993; Toriyama, 1984, 1944; Baum et al., 1970; Konishi, 1953) in the Gondwana-derived terranes.

In general, the geodynamic evolution can be summarized as follows: During the Upper Paleozoic, nearly the whole region discussed here was part of the northern continents forming Pangea—only a narrow belt in the West is built up by Gondwana-derived terranes, which docked during the Middle to Late Triassic. In Helmcke et al. (1993) and in Wang et al. (1997), we speculate that during the Upper Paleozoic and Triassic, the southern margin of the former northern continents was an active continental margin. However, the interpretation recently put forward by Meischner (oral communication) that this margin was a passive margin during most of the time, and may present a better solution.

The "non-Gondwana" regions are characterized by a highly mobile tectonic development with alternating phases of extensional and compressional deformation. A first phase of extension may have occurred at approximately 360 Ma. It created a rift-basin floored by oceanic crust ("ophiolites" of the Nan-Uttaradit region). This basin was closed during the Middle Permian (approximately 265 Ma) thus creating the intra-Permian unconformity described from Yunxian (Feng and Helmcke, in print). The last stages of this compressional deformation can be studied along the Lom Sak-Chum Phae highway in Central Thailand. Already during the Maokouan and Murgabian/Midian times, a new phase of extension created the first new depocenters. However, in many regions of Yunnan and Northern Thailand, the Lower Triassic is missing. This phase lasted until the uppermost Triassic was followed by the onset of a new transpressional regime.

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