Palaeogeography, Palaeoclimatology, Palaeoecology 290 (2010) 107–119

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

The Middle Carnian Wet Intermezzo of the Stuttgart Formation (Schilfsandstein), Germanic Basin

Heinz W. Kozur [a], G.H. Bachmann [b,*]

[a] Rézsü u. 83, H-1029 Budapest, Hungary
[b] Martin-Luther-Universität Halle-Wittenberg, Institut für Geowissenschaften,Von-Seckendorff-Platz 3, D-06099 Halle (Saale), Germany

ARTICLE INFO

Article history:
Received 9 March 2009
Received in revised form 29 October 2009
Accepted 3 November 2009
Available online 16 November 2009

Keywords:
Triassic
Carnian
Germany
Stuttgart Formation (Schilfsandstein)
Biofacies
Climate

ABSTRACT

The Middle Carnian Wet Intermezzo (MCWI) of the Stuttgart Formation (Schilfsandstein) and age-equivalent strata of the northwestern Tethys occurred entirely within equivalents of the upper subzone of the *Austrotrachyceras austriacum* ammonoid zone of the late Julian. Its duration is estimated to be only about 0.7–0.8 myr. In both the Germanic Basin and the northwestern Tethys, the warm climate during the MCWI was characterized by a rate of precipitation that exceeded somewhat the evaporation but was not so great as to be pluvial. The MCWI was related to the atmospheric circulation of a megamonsoonal system that was characterized by strong, moisture-laden, northwesterly flowing trade winds that rose as they reached the estimated 2000–3000 m high eastern shoulder uplift of a huge rift causing them to drop an extraordinary amount of rain. This eastern shoulder uplift lay within the Caledonides of modern day western Scandinavia. This region only, between 30 and 50°N palaeolatitude, had a truly pluvial climate, and the huge amounts of fresh water dropped there transported large amounts of siliciclastics from this rift-shoulder uplift southward into the Germanic Basin.

Before deposition of the siliciclastics an early Julian eustatic sea-level fall caused widespread erosion in the Germanic Basin. In the later part of late Julian, a transgression from the eastern gates with the concurrent strong fresh water influx from the north flooded the centre of the northern Germanic Basin with a shallow brackish sea in which the Osterhagen Horizon (Basisschichten) of the lower Stuttgart Formation was deposited. In the upper Osterhagen Horizon the salinity rapidly decreased from mesohaline through mio- and oligohaline to fresh water levels. In southern Germany the Basisschichten formed entirely within fresh water or very low salinity brackish environments. Later, a slight subsidence of the southwestern Germanic Basin shifted the main outflow of fresh water toward the southwestern end of the basin, creating local brackish conditions in the northern marginal part of the northwestern Tethys (e.g. in the Lunz Beds). During this time interval, tidal influence also can be found in the Stuttgart Formation deposited in palaeoestuaries of the southwestern Germanic Basin adjacent to the Tethys. The very strong fresh water influx from the north, however, prevented these estuaries from developing a strongly elevated salt content, so that only fresh water to oligohaline brackish faunas are found there such as the Eberstadt bivalve–conchostracan fauna.

At the base of the Tuvalian, the megamonsoonal system either disintegrated or else the trade winds shifted their principal flow direction. This caused the climate within the Germanic Basin and in the nearby northwestern Tethys Sea to become arid again as it had been before the deposition of the Stuttgart Formation. These changes in the atmospheric circulation patterns also terminated the pluvial climatic regime to the north along the Scandinavian eastern rift-shoulder uplift. This in turn ended the transport of huge amounts of siliciclastics from this region southward into the Germanic Basin and ended the deposition of the Schilfsandstein. After this, the hypersaline sabkha and playa sedimentation of the Weser Formation began, which was accompanied by some minor marine ingressions in the southwestern Germanic Basin.

1. Introduction

During the late Longobardian to late Tuvalian times the Germanic Basin was located between 20° and 30°N paleolatitude in the northern dry girdle around the Tropic of Cancer (Stampfli and Borel, 2004; Stampfli and Kozur, 2006). This time interval primarily was characterized by hypersaline sedimentation that formed the Grabfeld Formation (in the past referred to as Lower Gypsum Keuper) and its widespread deposits of gypsum and some halite (Bachmann and Kozur, 2004). The Tuvalian Weser Formation (in the past referred to as Upper Gypsum Keuper) consists likewise of hypersaline sediments that are rich in gypsum and locally contain halite. Thus, throughout

* Corresponding author.
E-mail addresses: kozurh@helka.iif.hu (H.W. Kozur), gerhard.bachmann@geo.uni-halle.de (G.H. Bachmann).

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doi:10.1016/j.palaeo.2009.11.004

the late Longobardian and Cordevolian times, and in Tuvalian time, the arid sedimentation occurring in the Germanic Basin matches well with the estimated palaeolatitudinal position of that area around the Tropic of Cancer and its northern low latitude dry girdle.

In contrast, climatic conditions were different during deposition of the middle Carnian (middle to upper Julian) Stuttgart Formation (Schilfsandstein). Kozur (1972, 1975) inferred for this time interval a wet climate that seemed not to fit well with the palaeogeographic position of the Germanic Basin at that time. Interestingly, during this same time interval, in the northwestern Tethyan Lunz and North Alpine Raibl formations brachyhaline marine to brackish intercalations occur with conchostracans and brackish ostracods, also indicating a strong fresh water influx. Schröder (1977) assumed a "perhaps more humid intermezzo" for the Schilfsandstein (Stuttgart Formation). Simms and Ruffell (1989) invoked a "Carnian pluvial episode" to explain this, and later authors referred to it as the "middle Carnian pluvial event". Visscher and Van der Zwan (1981), Van der Zwan and Spaak (1992) and Visscher et al. (1994), however, rejected such an interpretation and assumed that the deposition of the Schilfsandstein (Stuttgart Formation) occurred during a persistently arid climate in Carnian time. They postulated that the palaeogeographic setting of the Germanic Basin at that time was a kind of "Nile valley in a Carnian Sahara" (Visscher and Van der Zwan, 1981, p. 632). This interpretation is in fair agreement with the palaeogeographic position of the Germanic Basin around the Tropic of Cancer, but it is not supported by the facies of the Stuttgart Formation. The wide areal extent of the Stuttgart Formation fluvial facies only could be explained in this model by assuming an approximately 1000 km wide "Nile valley" in the northern part of the Germanic Basin and an at least 300 km wide "Nile valley" in its southern part—without any facies being present that would be equivalent to a surrounding Carnian Sahara.

This paper proposes that the Schilfsandstein clastics were derived from a rift-shoulder uplift located in the western Scandinavian Caledonides, in a depositional setting that was primarily controlled by climate, changes in sea level and local subsidence.

2. Carnian stratigraphy

The Carnian was originally subdivided into three substages: Cordevolian, Julian and Tuvalian (Mojsisovics et al., 1895). All three substages can be readily distinguished from each other (Fig. 1). The Cordevolian is characterized by a Carnian fauna which still contains, in all faunal groups, a considerable percentage of Ladinian faunal elements. Typical Carnian ammonoid genera like *Trachyceras* are present in the Cordevolian, but genera like *Frankites* (which appeared first in the upper Ladinian) still range high into the Cordevolian (Kozur, 1976; Balini and Jenks, 2007; Mietto et al., 2007). This often has led to assignment of the Cordevolian (or at least the *Daxatina canadensis* and the largely contemporaneous *Frankites sutherlandi* zones) to the Ladinian (e.g. Krystyn, 1974, 1978; Tozer, 1984). This no longer is possible, however, because the base of the Carnian since then has been defined as the base of the *D. canadensis* Zone (Fig. 1) as proposed by Broglio Loriga et al. (1998). This boundary is convenient not only for correlation within the Tethyan realm and with higher northern latitudes, but also for correlation with continental beds. Close to the base of the *D. canadensis* Zone there is a distinct change in sporomorphs. About 3.7 m above the base of the zone (total thickness almost 150 m in the proposed GSSP Stuores Wiesen section), is the first appearance of *Patinasporites densus* Leschik, *Vallasporites ignacii* Leschik and several other species, which are important for correlation with the Germanic Triassic. The conchostracan species *Laxitextella multireticulata* (Reible) first appears at the newly defined Carnian base, e.g., in the Germanic Basin (Fig. 1), where it begins together with a palynoflora with *P. densus* and *V. ignacii* (close to the FAD of these two species). Similarly, in the Newark Supergroup, Kozur and Weems (2007) have been able to recognize the base of the Carnian by the first appearance of *L. multireticulata*. Beside this Carnian conchostracan species, the late Ladinian *Euestheria minuta* (von Zieten) is still present in the entire Cordevolian.

Among conodonts, the Cordevolian contains the typical Carnian *Paragondolella noah* (Hayashi) plus other genera and species that continue up from the Longobardian, such as *Budurovignathus* and *Pseudofurnishius*. Among radiolarians, saturnalids (Parasaturnalidae Kozur & Mostler) begin at the base of the Cordevolian, even while the typical Middle Triassic Oertlispongidae Kozur & Mostler are still present. The same picture is seen in many other radiolarian groups. Within the stratigraphically important bivalve groups, the Upper Triassic *Halobia* first appears in the Cordevolian, but the Middle Triassic genus *Daonella* persists.

This mixture of Carnian and Ladinian elements in all stratigraphically important fossil groups can be observed throughout the entire Cordevolian (*Daxatina canadensis* Zone and *Trachyceras aon* Zone). In the Julian (*Trachyceras aonoides* Zone and *Austrotrachyceras austriacum* Zone), however, nearly all holdovers from the Ladinian have disappeared. Only one *Daonella* species persists into the *T. aonoides* Zone (Krystyn et al., 2002).

The base of the Tuvalian similarly is marked by distinct changes in most faunal groups, mainly among the nekton and plankton, but the deep water benthos do not change significantly and shallow water benthos (ostracods) are affected only moderately. Most striking is the turnover from the upper Julian ammonoids of the *Austrotrachyceras austriacum* Zone to the *Tropites* faunas of the lower Tuvalian and the changes from the Julian radiolarian faunas to the Tuvalian radiolarian faunas (Fig. 1). This latter group is characterized by the appearance of numerous new species within genera that were already present in the Julian, and also by the appearance of some entirely new groups (e.g. Unumidae Kozur, *Podobursa* Wisnowski, and the genus *Syringocapsa* Neviani, none of which achieve their widest distribution until the

Stage	Substage	Ammonoid zone	Conodont zone		Radiolarian zone	Ostracod zone	*Halobia* zone		Conchostracan zone
		Lower *G. jandidus* Zone	*E. orchardi-N. navicula*	*M. primitius*	*Capnodoce media - Nakasekoellus politus*		*Halobia austriaca*		*P. ? schwanbergensis*
CARNIAN	Tuvalian	*Anatropites spinosus*	*Carnepigondolella pseudodiebeli*					*H. radiata*	*L.freybergi-P.?schwan.*
									Laxitextella freybergi
			Carnepigondolella zoae		*Capnuchosphaera lea - Nakaskoellus inkensis*		*Halobia lenticularis*		
		Tropites subbullatus	*Paragondolella carpathica*			*S. nostorica*	*Halobia superba*		*Laxitextella seegisi*
			Paragondolella noah-P. postinclinata		*Spongotortilispinus moixi*				
		Tropites dilleri			*Elbistanium gracile*				*Eosolimnad. gallegoi*
	Julian	*Austrotrachyc. austriacum*	*Paragondolella noah - Gladigondolella tethydis*		*Tetraporobrachia haeckeli*	*Simeonella alpina*	*Halobia rugosa*		*L.* n.sp.-*Palaeol.* n.sp.
									L. cf. *laxitexta*-n. gen.
		Trachyceras aonoides					*Halobia fluxa*		
	Cordevolian	*Trachyceras aon*	*Budurovignathus diebeli - Paragondolella noah*		*Tritortis kretaensis*		*Halobia vixaurita-Daonella cassiana*		*Laxitextella laxitexta*
		Daxatina canadensis							*L. multireticulata*

Fig. 1. Biozonation of the marine and continental Carnian in the Tethys and in the Germanic Basin. The Carnian–Norian boundary is not yet defined. Vertical axis does not reflect the relative temporal duration of these biozones. *G. jandianus* = *Guembelites jandianus*; *E. orchardi–N. navicula* = *Epigondolella orchardi–Norigondolella navicula*; *M. primitius* = *Metapolygnathus primitius*; *L.* cf. *laxitexta* - n. gen. = *Laxitextella* cf. *laxitexta* - n. gen. cf. *fimbriata*; *L.* n. sp. - *Palaeol.* n. sp. = *Laxitextella* n. sp. - *Palaeolimnadia* n.sp.; *P.* ? *schwan.* = *Palaeolimnadia* ? *schwanbergensis.* Ammonoid column after Krystyn (1978) and Krystyn et al. (2002). Conodont column after Kozur (2003). Radiolarian column after Kozur and Mostler (1994) and this paper. Halobiid column slightly modified from Krystyn (1978), Krystyn et al. (2002) and McRoberts (2007). Conchostracan column modified from Kozur and Weems (2007, in press).