Sedimentology, Microfacies and Age Dating of the Samana Suk and the Chichali Formations (Middle to Late Jurassic) from the Punjab Platform, Pakistan

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Abstract

Detailed sedimentological, biostratigraphical and microfacies studies from three cores (one from the Ali Sahib Well and two from the Amir Wali Well) from the Punjab Platform in Pakistan result in a more precise age dating (Middle to Late Jurassic)of the Samana Suk Formation and the Chichali Formation. In both wells the microfacies reflect depositional environment ranging from deep- to shallow-marine. The Middle Jurassic in the lower part of the section is characterized by the occurrence of radiolarians and *Bositra*-shells. The Late Jurassic sequence contains *Saccocoma* and *Nautiloculina oolithica*. This is the first direct age dating from boreholes of the Jurassic strata from Punjab Platform in Pakistan. *Saccocoma* was found in the nuclei of oncoids and is also present in the micritic matrix. The shallow-water organisms occur partly as nuclei of the micritic oncoids and partly resedimented. The investigated successions reflect a complex transgressive-regressive pattern of the sedimentary succession in an outer shelf position. From the microfacies characteristics, we reconstruct an outer ramp position of the investigated samples. The shallow-water material derived from areas known more in the north.

Introduction

In 2005, Oil & Gas Development Company Limited drilled up to the target depth of 2050 m (from Recent to Jurassic) Ali Sahib and Amir Wali wells in the Punjab Platform for the exploration of hydrocarbons (for location see Fig. 1). In Jurassic, the Datta and Samana Suk Formations were encountered in the bore holes. The Datta Formation consists mainly of clastic sediments, while the Samana Suk Formation is mainly comprised of carbonates (Fig. 2).

The Samana Suk Formation (Middle Jurassic: Shah 1997, Fatmi 1977) is a significant sedimentary succession. Its thickness varies from 5 m (Nammal Gorge, Salt Range) to 366 m (Sheikh Buddin Hills, Marwat Range). It is also recognizable over a wide area of northern Pakistan (Shah 1977, Nizami & Sheikh 2007). Due to the presence of ooids, the depositional environment of the Samana Suk Formation in the study area was considered as shallow-marine (Shah 1977), comparable with the well investigated successions in the Surghar Range and in the Trans Indus Ranges in Pakistan (Nizami & Sheikh 2007). Fatmi (1977) reported in these areas from the top of the Samana Suk Formation the ammonite taxa *Reinneckeia ancepto*, *Choffatia* sp., *Obtusicostites* sp., *Hubertoceras* sp., and *Kinkeliniceras* sp. (Middle Callovian).

The Chichali Formation (Danilchik 1961, Gee 1947) is overlying the Samana Suk Formation and it is mainly comprised of glauconitic shale and glauconitic sandstones in all the exposed regions (Salt Range, Trans Indus Ranges and in Hazara area). According to Fatmi (1977), the Chichali Formation is mainly of Late Jurassic age. Kazmi & Jan (1997: pp. 221) assigned a Late Oxfordian to Neocomian age to the Chichali Formation. Ashraf determined on the basis of nannofossil biostratigraphy (by studying cuttings of the Ali Sahib Well) the age of the Chichali Formation as Early Cretaceous (unpublished report of OGDCL 2005). According to him, below the Chichali Formation (which is mainly a clastic sequence), the carbonate sequence is Jurassic in age and can be considered as the Samana Suk Formation. But, in general, there exists up to now no general agreement about the age ranges of the different formations: Mertmann & Ahmad (1994) and Nizami & Sheikh (2007) assigned the Samana Suk Formation to the Middle Jurassic, overlain by the Late Jurassic to Early Cretaceous carbonatic-siliciclastic Chichali Formation (Qureshi et al 2007). Fatmi (1977) assigned a Late Oxfordian to Early Cretaceous age of the Chichali Formation. In contrast, Köthe (1988) mentioned an Oxfordian to Tithonian age.

According to Mertmann & Ahmad (1994), the base of the Samana Suk Formation should be diachronous (Bathonian to Callovian) and its deposition should end in the Callovian. The Chichali Formation starts its deposition in Late Oxfordian after a gap. All these data came from the Surghar Range and Salt Range in Pakistan further to the

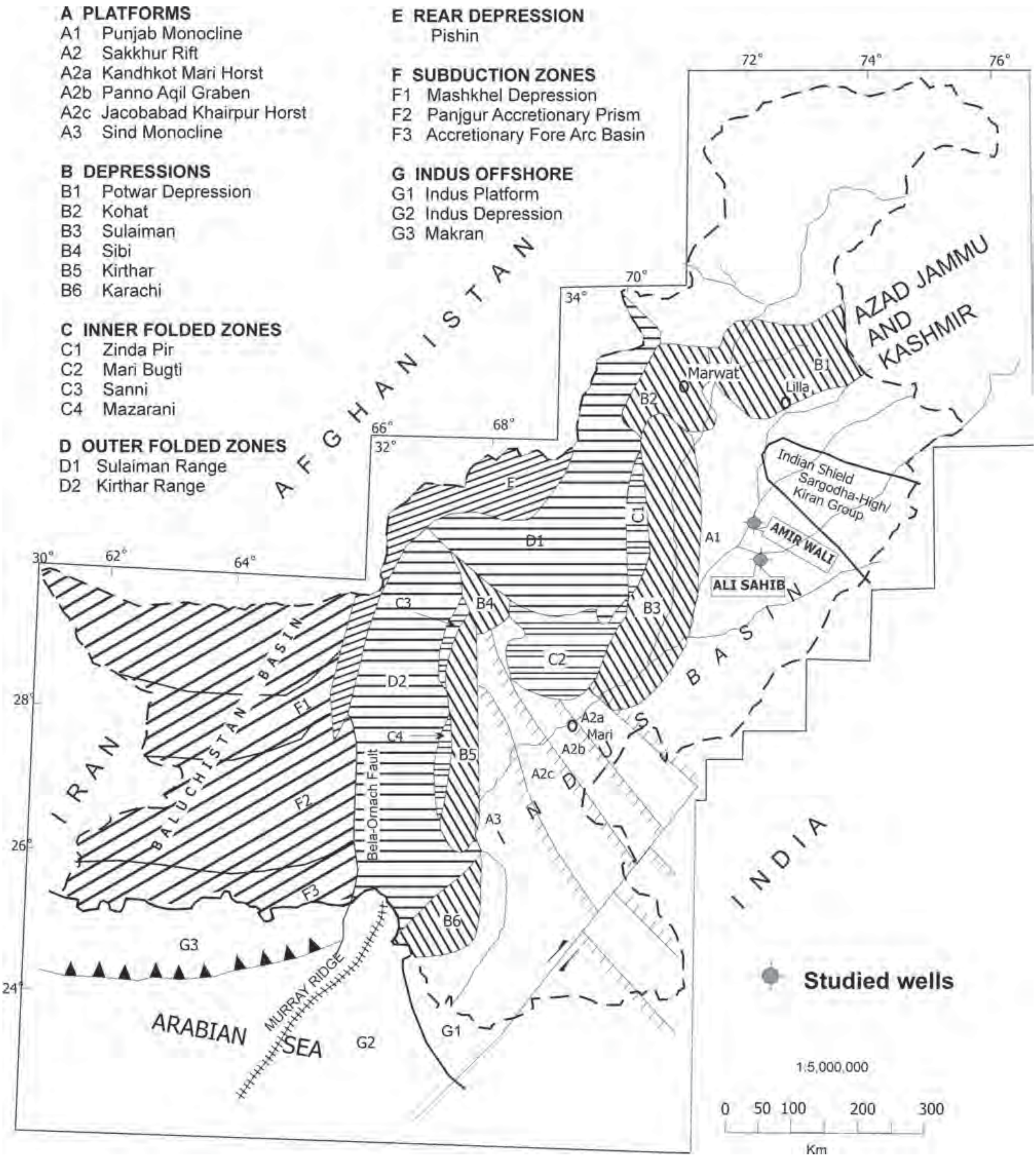
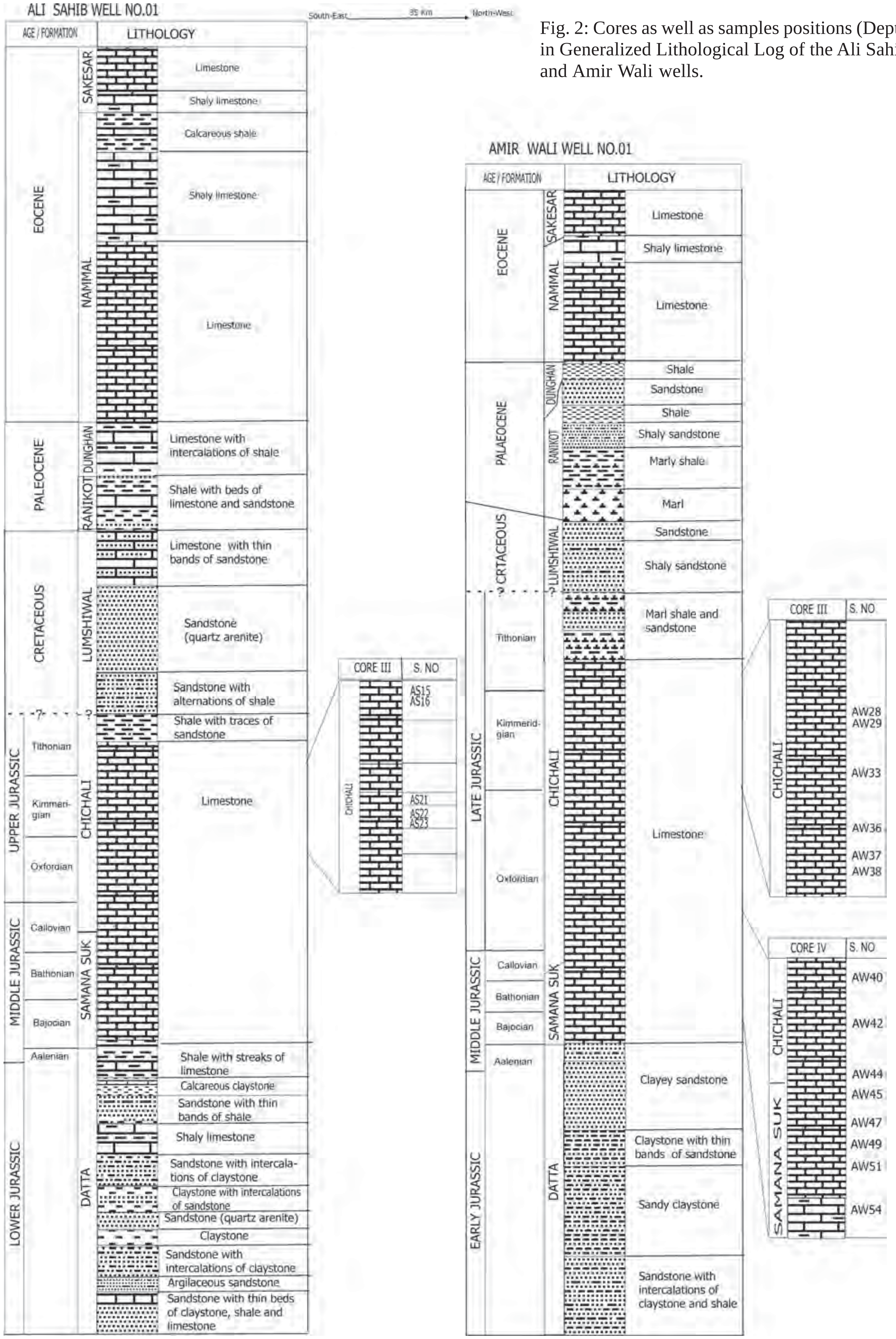


Fig. 1: Locations in the Geological map of Pakistan of the studied wells Ali Sahib and Amir Wali, drilled by OGDCL in 2005.

north and northwest. This northern and in Jurassic times more continentward region is highly affected by sea-level fluctuations and therefore gaps occurs (Mertmann & Ahmad 1994) during regressive cycles. Deposition is mainly characterized by shallow-water conditions (e.g., Hallam & Maynard 1987, Nizami & Sheikh 2007, Qureshi et al 2007). Only a transgressive cycle in the Middle Callovian provide exact data to separate the Samana Suk and Chichali Formations (dated with ammonites - see above). A similar succession with comparable microfacies characteristics has been encountered in the Ali Sahib and Amir Wali wells and was therefore assigned as Samana Suk Formation. Its thickness is 142 m and 140 m in the Ali Sahib and in the Amir Wali Well respectively (Fig. 2). But the correlation with the shallow-water areas to the north is rather unclear due to the lack of exact data. The investigated wells provide the first data from an environment located in more outer shelf position.

Fig. 2: Cores as well as samples positions (Depth in Generalized Lithological Log of the Ali Sahib and Amir Wali wells.



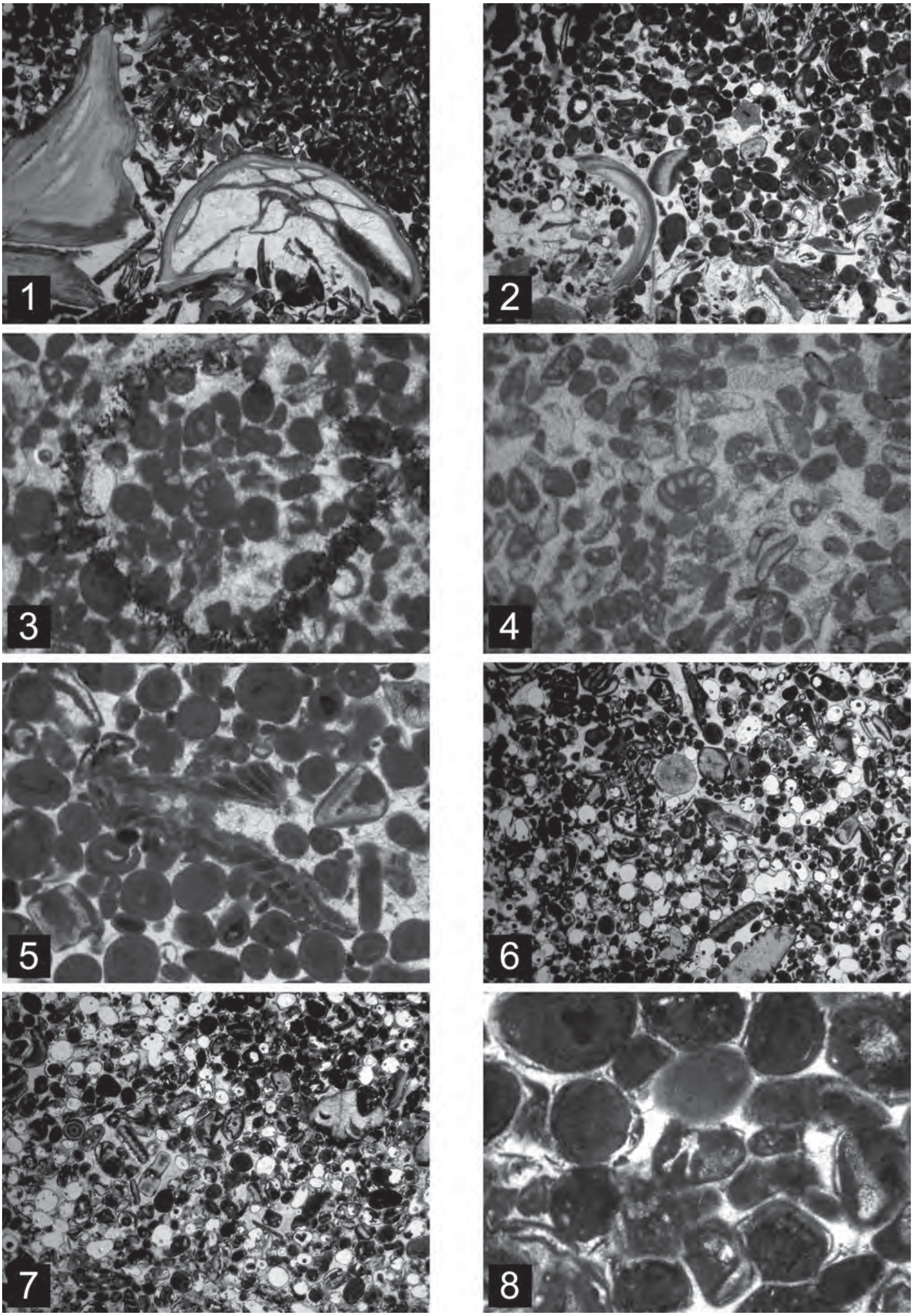

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Fig. 3: Characteristic microfacies of the Chichali Formation (?Callovian to ?Tithonian) of the Ali Sahib Well, Core II. Page 20.
1. Brachiopod shells together with micrite ooids. Sample AS 23. Width of the photo: 1.4 cm. **2**. Grainstone with micrite ooids, encrusted brachiopod fragments and crinoids. Sample AS 21. Width of the photo: 1.4 cm. **3**. and **4**. *Nautiloculina oolithica* in sample AS 22. Width of the photo: 0.25 cm. **5**. Micrite ooids with bryozoans and encrusted crinoids. Sample AS 21. Width of the photo: 0.25 cm. **6**. Micrite ooid facies with small benthic foraminifera, crinoids and recrystallized carbonate clasts. Such micrite ooids indicate deeper water environments. Characteristic are also the crinoids without encrusting. Sample AS 16. Width of the photo: 1.4 cm. **7**. Similar microfacies from the uppermost part of the core. Sample AS 15. Width of the photo: 1.4 cm. 8. Encrusted *Saccocoma*. Sample AS 15. Width of the photo: 0.25 cm.

Geological Setting

The Punjab Platform is a part of Indus Basin (the Jurassic Passive continental margin of Asia) and it forms today a gentle monocline eastward of the Indus Basin (Fig. 1). The Punjab Platform is subdivided by the Sargodha High (Indian Shield) in a southern and northern part, and is a NW-SE trending regional structure (Kazmi & Jan 1997). An eastward continuation of the Platform was named Rajasthan Shelf by Verma (1991). Geophysical surveys (Balakrishann 1977, Farah et al. 1977, Seeber et al. 1980, Malik et al. 1988) and remote sensing studies (Kazmi 1979, Kazmi & Rana 1982, Kazmi & Jan 1997) indicate that the basement is extensively traversed by NNE to NE, NNW E-W trending faults.

Stratigraphy, Microfacies and Age Dating

Ali Sahib Well Core III: Chichali Formation (Oxfordian to early Tithonian 1694 to 1701 m)

The microfacies pattern of this core reflects a complex palaeoenvironment. Most dominant are grainstones with shallow-water clasts, including coated grains, bryozoans, shell fragments, brachiopods, micrite ooids and several benthic foraminifera. Of special interest is the occurrence of *Saccocoma* as nucleus in micritic oncoids/ooids together with rare occurrence of *Nautiloculina oolithica*. Both together indicate an Oxfordian to Tithonian age. Of special interest is the material shed from the shallow-water carbonate ramp, together with a huge amount of crinoids, beside the micrite ooids (in the sense of Jenkyns 1972), both indicate a deposition in an outer shelf region. This microfacies type corresponds more or less to the microfacies of the Samana Suk formation as described in the north Mertmann & Ahmad (1994), but is younger. The age range perfectly corresponds to the age of the Chichali Formation, but lithology and microfacies are completely different.

Amir Wali Well: Microfacies Studies in Core III and Core IV of the Samana Suk Formation of (Oxfordian to early Tithonian)

In the Amir Wali Well two cores were investigated, the lower core was from a depth of 1862 to 1853 m and the upper core was from a depth of 1769 to 1760 m. The section of lower core (Core IV) starts with allodapic limestones in a radiolaria-rich wackestone and shows a general shallowing upward cycle. The microfacies of the samples of the sequence of the lower core are characterized by siliciclastic influenced shallow-water carbonates, which consist mainly of grainstones. The grainstones are rich in shells, peloids, small benthic foraminifera and rare oncoids. Micrite clasts are common, ooids are completely missing. In the upper part of this succession (Core IV), the first *Nautiloculina oolithica* was found. This foraminifer is limited to the Bathonian to Tithonian. Upsection follows a deep-water succession, which consists of a filament-radiolarian packstone. The filaments resemble *Bositra*-shells, characteristic for the Middle Jurassic to Oxfordian. *Bositra*-Limestones are known widespread in the Middle Jurassic of Tethyan realm. These *Bositra*-Limestone contains several allodapic limestone layers. The components of these mainly shallow-water derived carbonates differ from that in the deeper parts. Upsection less shells and peloids are characteristic. Dominant are crinoids, beside micrite ooids in several layers. Small benthic foraminifera, bryozoans, brachiopods fragments are common. Partly micrite ooids are dominating, partly occur *Saccocoma* in the core of these micrite ooids.
In several samples the occurrence of *Nautiloculina oolithica* proves, beside the occurrence of *Saccocoma*, an Oxfordian to Tithonian age of the succession drilled in the upper core (Core III) as well as in the upper part of the lower core (Core IV). Both sections (Core III and Core IV) are characterized by shallowing-upward cycles with radiolaria-wackestones at the base representing independent shallowing-upward cycles.
The microfacies of the lower part of the Core IV is different from the microfacies as known from the Samana Suk Formation. But the age range (Bathonian to Callovian) corresponds perfectly to the defined age of the Samana Suk Formation as known from the literature. The upper part of Core IV and Core III corresponds to the described microfacies if the Samana Suk Formation in the literature, but in age range it is younger (Late Callovian to ?Tithonian).

Discussion

Based on our new data we correlate the sedimentary sequences as follows (Fig. 3)
1. The lower part of the succession in Core IV of the Amir Wali Well can be correlated with the Samana Suk Formation: Bajocian to Early Callovian. But the microfacies

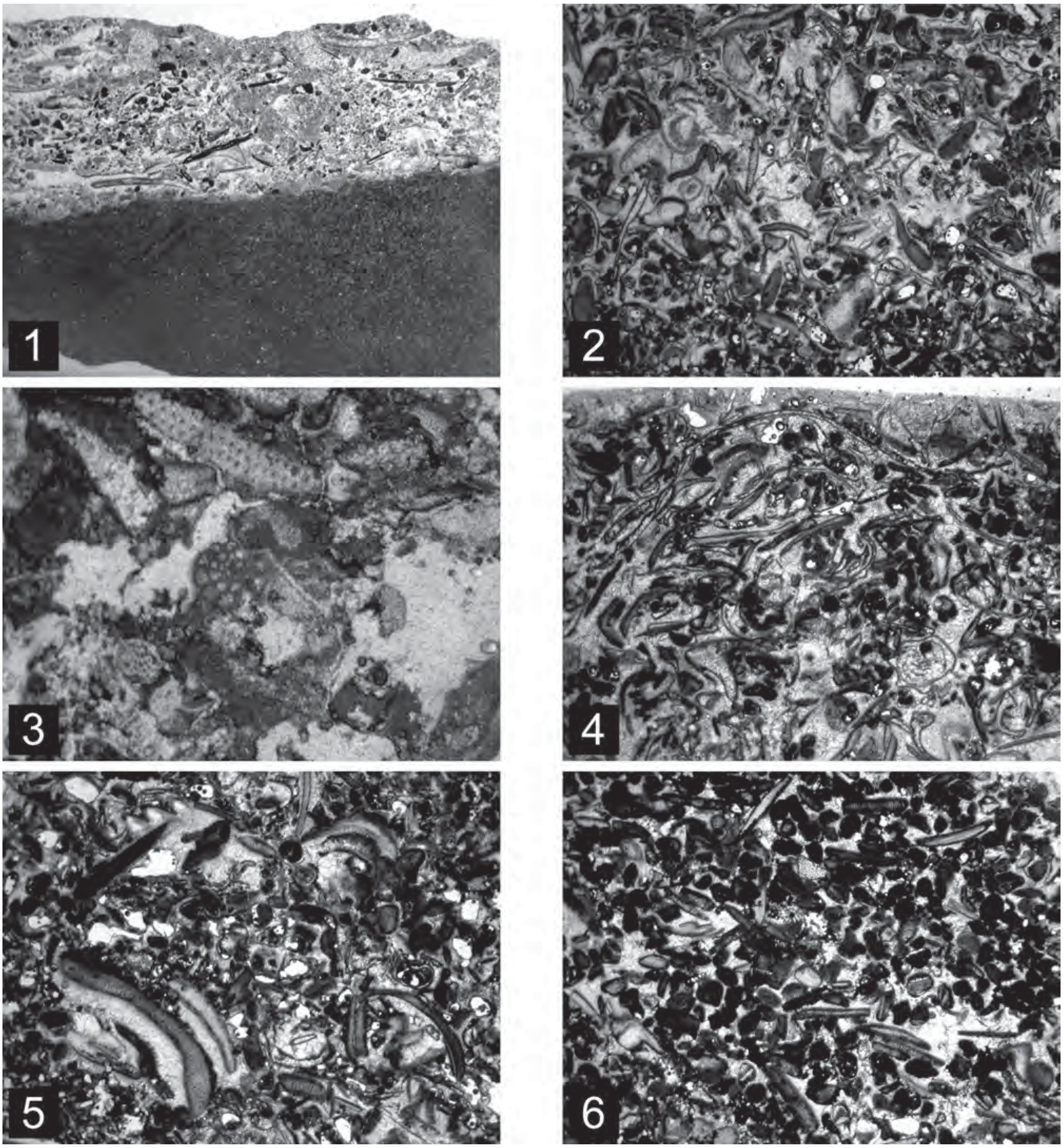


Fig. 4: Characteristic microfacies from the Samana Suk Formation (Middle Jurassic) of the Amir Wali Well Core IV, lower part. **1**. Allodapic limestone on top of a radiolarian wackestone. Radiolarians are recrystallized. Sample AW 54. Width of the photo: 1.4 cm. **2**. Grainstone with micrite clasts, shells with iritic envelopes, crinoids remnants and bryozoans. Sample AW 51. Width of the photo: 1.4 cm. **3**. *Nautiloculina oolithica* in the central part of the photo. Sample AW 49. Width of the photo: 0.25 cm. **4**. Grainstone enriched in shells together with micrite clasts. All shells with micritic envelope, partly with borings. Sample AW 48. Width of the photo: 1.4 cm. **5**. Beside the shells, crinoids and micrite clasts some quartz grains occur. Sample AW 47. Width of the photo: 1.4 cm. **6**. The same microfacies as in the lower part of the succession is visible in the upper part of the succession. Well sorted grainstones are dominating indicating a still identical depositional environment as well as a similar source area of the carbonate clasts. Sample AW 45. Width of the photo: 1.4 cm.

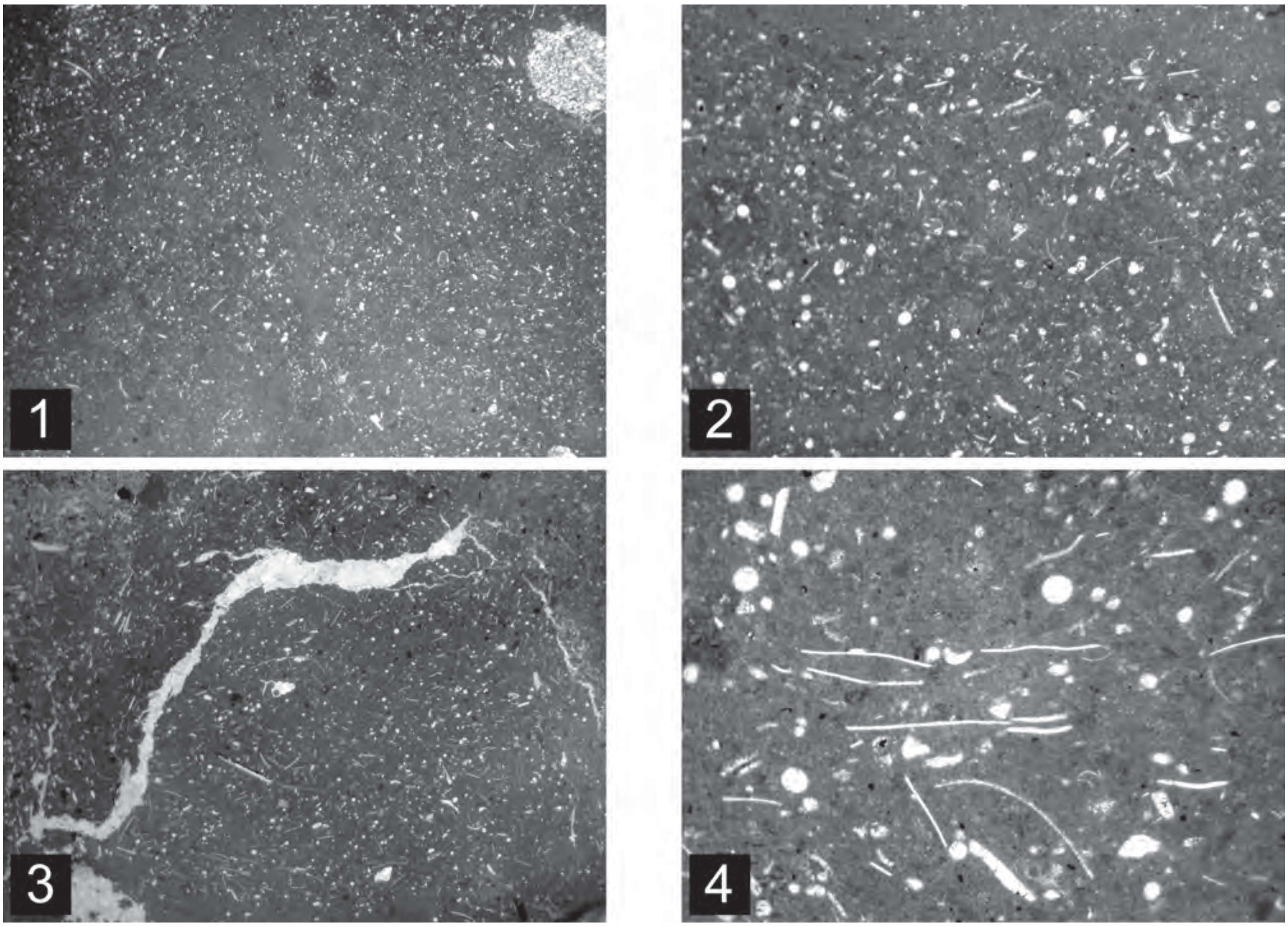


Fig. 5: Hemipelagic *Bositra*-Limestone (Callovian) intercalation in the upper part of the Amir Wali Well Core IV. All figures show a radiolarian and *Bositra*-rich filament limestone as typical in the Middle Jurassic of the Tethyan realm. **1**. Sample AW 44. Width of the photo: 1.4 cm. **2**. Magnification of 1. Width of the photo: 0.25 cm. **3**. Sample AW 42. Width of the photo: 1.4 cm. **4**. Magnification of 3. Width of the photo: 0.25 cm.

is different. Here in the outer shelf region deposition may start earlier as in northern Surghar Range (Mertmann & Ahmad 1994). The succession evolved in a shallowing-upward manner.

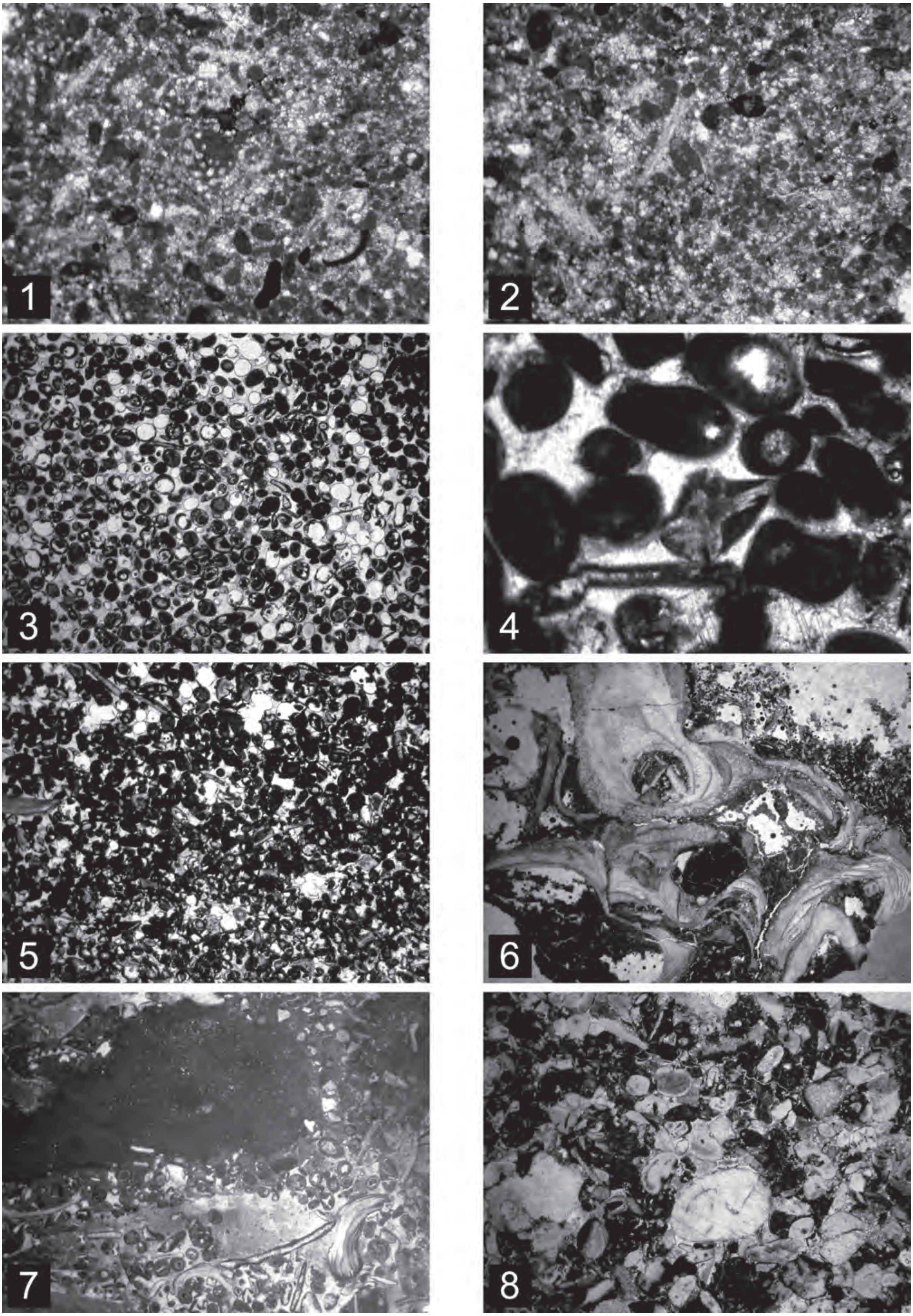
2. The upper part of the succession drilled in the Amir Wali Well as well as in the Ali Sahib Well, we correlate with the lower part of the Chichali Formation (Middle Callovian to Tithonian). But the microfacies correspond to the Samana Suk Formation.

The onset of deposition of shallow-water material is slightly earlier as in the north (Late Oxfordian), due to its palaeogeographic position more on the outer shelf area representing a regressive cycle. The *Bositra*-Limestone on the base may have an age range from Callovian to Oxfordian, as indicated by the occurrence of *Nautiloculina oolithica* below and above. Only above this *Bositra*-Limestone horizon appear *Saccocoma*, which lasted until the Tithonian.

Conclusions

· The sediments of the Samana Suk Formation and the Chichali Formation were deposited in an outer, deeper shelf region of a carbonate ramp setting as documented by the occurrence of shallow-marine carbonate clasts and

Fig. 6: Characteristic microfacies of the Chichali Formation (?Callovian to ?Tithonian) of the Amir Wali Well, Core III. Page 24.
1. and **2**. *Nautiloculina oolithica* in sample AW 40. Width of the photo: 0.25 cm. **3**. Micrite ooid facies with small benthic foraminifera, crinoids and recrystallized carbonate clasts. Such micrite ooids indicate deeper water environments. Sample AW 38. Width of the photo: 1.4 cm. **4**. *Saccocoma* as nucleus of a micrite ooid. Sample AW 37. Width of the photo: 0.25 cm. **5**. Micrite ooid facies similar as sample AW 38, but with some shells and more crinoids, partly without encrusting. Sample AW 36. Width of the photo: 1.4 cm. **6**. Colony of encrusted shells building a bioherm. Sample AW 33. Width of the photo: 1.4 cm. **7**. Large wackestone clast with radiolarians as plasticlast in a grainstone, consist of micrite ooids, encrusted brachiopod shells and crinoids. Sample AW 29. Width of the photo: 1.4 cm. **8**. Poor sorted crinoidal sand with micrite clasts. Sample AW 28. Width of the photo: 1.4 cm.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deeper water organisms mixed together. Quartz grains occur only in the Samana Suk Formation.

- Fossils dating prove an age and Late Callovian to Early Tithonian for the lower part of the Chichali Formation.
- The lithology of lower part of the Chichali Formation comprised mainly of carbonates and corresponds to the Samana Suk Formation to the north.
- The occurrence of *Bositra*-Limestone on the base of the Samana Suk Formation proves a Late Middle Jurassic age most likely of Callovian age. *Nautiloculina oolithica* below proves a younger age than Bathonian.
- The intercalated *Bositra*-Limestone may have an age of Callovian and may be correlated with the Middle Callovian transgression in the Surghar Range.

Due to scarcity of available material of the wells more precise correlation are impossible. Therefore a lot of questions, especially for the correlation of the formations, remains open and need further investigation.

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