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Non-marine Carbonate (Joint/Dike) Filling In The Injana Formation, Kand Anticline, NE-Iraq

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ABSTRACT

Riparian clastic beds of fluvial origin in the Injana Formation (Upper Miocene) of Kand anticline exhibit the development of a vertical joint/dike like structure in host sandstone overlying red mudstone. These structures indicate filling from above with sandy carbonate showing texture of floating clastic grains in a micritic calcite stained with red iron oxide pigment. This is capped by siltstone-very fine sandstone enriched with iron oxide and preserved diatom vestiges as chert spheroids; accompanied by oval-irregular vugs lined with microcrystalline calcite. These beds are topped by fossil-barren micritic carbonate of intraclastic texture.

The clastic-carbonate package is interpreted as non-marine fluvial-lacustrine deposits of interchannel depression (pond-lake). Episodic exposure with incipient plant root penetrations, desiccation and differential compaction have led to fissure cracking; otherwise tectonic jointing is entailed. A terminal stage of enlargement by descending water was conducive to the genesis of these joint/dike structures which were filled later by reworked, reshaped and modified sediments sourced from juxtaposed-nearby areas.

الكاربونات غير البحرية (مالئة الفواصل / القواطع) في تكوين انجانة طية قند المحدبة شمال شرق العراق

الملخص

تحتضن رواسب ضفاف الأنهار لتكوين إنجانة (المايوسين الأعلى) في طية قند المحدبة تراكيب فواصل/قواطع في الصخور الرملية تسفلها صخور طينية حمراء. وهذه التراكيب توضح ان ملأها كان من الأعلى برواسب فتاتية-كاربوناتية ذات انسجة تكتنف حبيبات طافية داخل كالسايت دقيق التبلور (مكرايت)، مع ترافق صبغة الحديد. وهذه مطبق عليها برواسب من السلت والرمل الناعم جدا المغتنية بصبغة الحديد وتحفظ اثار للداياتوم بهيئة كريات من السيليكا ويترافق معها ثقوب بيضوية-غير منتظمة مبطنة ببلورات ناعمة من الكالسايت. ويعلو هذه الترسبات طبقة كاربوناتية-مكراتية خاوية من المتحجرات وذات نسيج من فتات الكاربونات.

ان رزمة الرواسب الفتاتية-الكاربوناتية هذه تمثل رواسب غير بحرية نهرية-رواسب بحيرات تطورت ما بين القنوات النهرية كمنخفضات لتجمع المياه الهادئة. ان فترات الجفاف والانكشاف السطحي ادى الى نمو

النباتات واختراق جذورها للرواسب، جفافها وتشققها، أو ان التشققات نشأت بفعل الانضغاط التفاضلي والا فانهـا تقترن بفواصل تكتونية. والمرحلة الأخيرة تضمنت توسيع هذه الشقوق بواسطة المياه المدورة النازلة ومـن ثـم امتلائها بفتات الترسيب، محور ومشتق من مصد محلي قريب.

INTRODUCTION

Filled fissures in sandstone are common features indicating either clastic dikes as a result of forcible injection-intrusion of sand from above or below (Pettijohn, 1957; Marschalko, 1978) or accumulation of grain by grain as settling deposits in vertical dissolution hollows, desiccation cracks and enlarged root tracks in fluvial and pedogenic calcrete-caliche profiles (Knox, 1977; Freytet, 1984; Gierlowski-Kordesh, 1998).

The filling can be similar to that of the host rock, sandstone cemented carbonate or even carbonate alone. The majority of clastic dikes are, however, consist of fine-medium grained sandstone, well cemented by calcite. Desiccation cracks upto 1 m in depth is characteristic of mudstones alternating with sandstones of alluvial plain sediments comprising channel-floodplain, levee crevasse splay-pond couplets. Non-marine carbonates may include lacustrine (Tucker, 1990), calcrete/caliche (James, 1973; Freytet, 1984), lakes in river floodplain (Friend and Moody-Stuart, 1970), and as micrite associated with siliciclastics in various continental environments (Gierlowski-Kordesh, 1998).

The Injana Formation is characterised by the development of “fining-upward” fluvial cycles (Buday, 1980; Al-Banna, 1982; Al-Fattah, 2001). These cycles consist of alternating channel-bar sandstone and floodplain-overbank siltstone-mudstone. The present study documents the occurrence of a variety of joint/dike structure and associated carbonate within these sediments and focuses on their genesis following the envisioned depositional environment of the host sediments.

GEOLOGIC SETTING

The Upper Miocene fluvial clastic sequence of Injana Formation is well exposed in the Foothill Zone of Iraq which is dotted by numerous anticlines among them is Kand anticline; where the area of the present study is located on its northern limb (Fig.1). The surface stratigraphy includes the Fat`ha Formation (Middle Miocene) outcropping in the core and consisting the thickly bedded evaporites interbedded with green and red marls and some thin limestone intercalations about 197 m thickness (Gosling and Botton, 1959; Shaban et al., 1971; Al-Banna, 2002). The Injana Formation occupies the greater part of the exposed strata on the limbs of the structure and is made up of reddish-brown sandstone interbedded with red siltstone-mudstone with variable thickness 333-470 m depending on location of the measured section (Al-Banna, 2002).

The investigated profile (Fig.2) occurs in the middle part of the sequence of Injana Formation and attains 2.3 m in thickness. The basal bed is jointed red mudstone overlained by 1-5 m thick structureless red sandstone hosting the joint/dike like structure, which extends 1 m in depth and 15-20 cm in width. This is capped by 20-30 cm thick red siltstone-very fine sandstone and the latter is in turn topped by 30-50 cm thick bed of massive carbonate. However, the exact thickness is constrained by limited exposure near road cutting.

Fig. 1 : Location map showing the study area and the surface lithostratigraphy of Kand anicline

Fig. 2 : Sketch of outcrop-photo illustrating the configuration of lithofacies enclosing the Joint/dike filling(D). Man for scale (175cm.).

The present study describes the occurrence of these joint/dike features, hitherto, unreported previously from the Injana Formation.

LITHOFACIES

Figure (2) is a sketch of outcrop-photo illustrating the configuration of lithofacies recorded from the clastic-package which envelope the joint/dike structure and associated carbonate. They are described below following their schematic distribution.

Lithofacies A

It occurs at the base of the measured section whose lower contact is not observable. The bed consists of red-mudstone, highly jointed and fractured. It is massive, faintly laminated with vague alternation of slightly clear calcareous clay and red-stained siltstone. Thin section study shows it to consist of angular-subangular fine quartz grains (0.05-0.1 mm) set in groundmass of clayey carbonate micrite impregnated with iron oxide and mud pellet of distorted shape (Fig.3). Scarce chert grains (0.2 mm) consist of microcrystalline quartz are present. Dissolution has resulted in irregularly distributed vugs, which partly lined with microcrystalline calcite.

Lithofacies B

It represents the host sandstone which is structureless, medium-coarse grained; consisting of quartz (50-70%;), carbonate grains (20-30%) and plagioclase (1-2%) embedded in recrystallised calcite-microspar stained with iron oxide (Fig.4). Vuggy porosity appears as a sequel of dissolution of oval-spherical shaped unidentifiable constituents accompanied by recrystallization of micritic grains into microspar.

Lithofacies C

This bed intermingles indistinctively as topping to the joint/dike materials. It appears as red fine-grained sandstone. Petrographically it consists of quartz grains (75%) ranging in size from 0.2-0.6 mm and individual grains are surrounded or enclosed by a rind of iron oxide embedded in a groundmass of microspar stained with iron oxide (Fig.5). Minor plagioclase feldspar is present with subordinate chert spheroids and carbonate rock fragments (0.2-0.4 mm). Nearby, subsample shows lesser content of constituents with concomitant increase in groundmass-iron oxide content. The iron oxide rimming quartz grains and the impregnated microcrystalline calcite impart a network or cellular appearance to the texture reminiscent of pedogenic processes. The leaching of carbonate grains leaves dissolution vugs of variable and ramified shapes lined with granular calcite (Fig.4). Few spindle-spherical shaped grains about 0.3 mm in size consist of chalcedonic-microcrystalline quartz and on one occasion diatom shell is identified. Diffused pelletoids-mud grains permeated with non-oxide are scattered throughout the groundmass.

Lithofacies D

It constitutes the tapering downward joint/dike filling which is in sharp contact with the host sandstone. Under thin section study it exhibits a floating texture of quartz (25%) in a buff-brown microcrystalline calcite (Fig.6). Quartz grains are subangular in shape reaching 1 mm in diameter but the majority between 0.2-0.4 mm. Few composite grains of quartz are poly-monocrystalline showing both igneous and metamorphic affinity.

Fig. 3 : Thin section, plane light, lithofacies A, angular-subangular fine-grained quart/ , pelletoids in groundmass of calcareus clay- clayey carbonate micrite. (40x.bar 0.05 mm).

Fig. 4 : Thin section, plane light, lithofacies B, Quartz and carbonate clasts enclosed by recrystallized microspar stained with iron oxide. Dissolution vugs lined with microcrystalline calcite (52x.bar 0.5 mm).

Fig. 5 : Thin section, plane light, lithofacies C, fine-grained sandstone consisting of quartz and mud-grains set in groundmass of microspar stained with iron oxide (40x.bar 0.2 mm).

Fig. 6 : Thin section, plane light, lithofacies D, hostfilling of quartz and mud-pellets floating in microcrystalline cacite stained wih iron oxide Assorted vugs, partly lined with microcrystalline cacite. (52x.bar 0.3 mm).

Dissolution vugs are lined with granular calcite and become irregular and enlarged where interconnected (root traces or chara). Few chert grains and mud pellets are also present but scarce.

Lithofacies L

It is present as discontinuous carbonate bed with patchy distribution capping lithofacies C. It appears as massive, dense, reddish carbonate. Microscopic study shows it to be as amalgamated micrite-intraclasts welded together giving a micritic texture, devoid of fossils and other allochems.

CHEMICAL COMPOSITION OF JOINT/DIKE FILLING

Chemical analysis of the sandy carbonate filling reveals the following percentages of the major oxides, SiO_2 (26.78%), Fe_2O_3 (1.39%), Al_2O_3 (3.40%), TiO_2 (0.25%), CaO (34.44%), MgO (1.70%), Na_2O (0.92%), K_2O (0.88%), SO_3 (<0.07%), Cl (0.01%), L.O.I (28.98%); which compare well with marl. Recalculation indicates a carbonate content of 62% by weight, present as calcite as demonstrated by microscopic study. The low contents of Na_2O, K_2O, TiO_2 and MgO when cross-referenced to Al_2O_3 show a subdued clay mineral and/or plagioclase proportions. The Fe_2O_3 is allocated to iron oxide as a result of pedogenic mamorization and concomitant emplacement of the joint filling with quartz, chert and a micritic calcite as settling deposit.

INTERPRETATION

Corollary deduction of depositional environment of the sediments enclosing the joint/dike structure is relevant to the predictive interpretation of their genesis.

The fossil barren character of interbedded mudstone and structureless-faintly laminated sandstone hosting the joint/dike structure, is commonsurable with the unanimously held view of non-marine fluvial environment for the Injana Formation (Al-Mubark, 1978; Al-Banna, 1982; Buday, 1980); although tidal-flat, lacustrine, lagoon-deltaic developments in the lower part of the succession have been reported (Buday, 1980; Al-Fattah, 2001).

The red mudstone-sandstone couplet, however, with endemic carbonate are commonly considered as channel and riparian-overbank deposits in alluvial, palustrine-lacustrine complex or fandelta-distal fan in lagoon-bay setting (Gierlowski-Kordesh, 1998). Specified association has been considered as levee, sand sheets and splay deposits on floodplain protecting interchannel lake-pond in siliciclastic dominated rivers (Freytet, 1984; Aqrawi and Evans, 1994; Jo and Chough, 2001). These decantation ponds or lakes, among sandy channels, develop on the subjacent muddy floodplain as depressions receiving both detrital silicates and clastic micritic carbonate from surrounding areas. Episodic exposure often leads to the action of pedogenic processes to paleosol development with their diagnostic features. The latter include complex network of desiccation cracks, brecciation, modular-lamined-massive and chalky caliche, calcareous tubules, vertical fissures, root traces and dissolution vugs surrounded by halos or lined with microcrystalline iron stained calcite; in addition to redness caused by iron oxide pigments.

Nevertheless, ephemeral lakes are growth sites of calcareous charophyt and their accumulated remains (Friend and Moody-Stuart, 1970; Freytet, 1984) and the same lake fluctuates from fresh to saline with time (Picard and High, 1972). Chara has been reported from other localities of Injana Formation (Lawa, 1995); whereas in the present study their presence is suspected but not proved. Not withstanding, some of the halos are oval-spherical and irregular in shape and lined by microicrystalline calcite (Fig.4). As such, they display affinities to root traces accompanied by dissolution, recrystallization micrite and redistribution of iron oxide in the vadose-phreatic zone, particularly above water-table, in a well drained environment (James, 1972; Knox, 1977; Freytet, 1984). Microfabric study of paleo-desiccated crusts demonstrates that the release of iron oxide acts as a cementation agent and binds the detrital grains giving a more compacted fabric (Tovey et al., 2002). Likewise, paleosols with abundant iron oxides occur in dissolution hollows (Espejo et al., 2002). Most of these attributes are exhibited by the sandstone-siltstone enclosing the joint/dike structure in the Injana example; consequently, they would enhance the ability to specify them as levee-splay deposits exposed to alternative wetting and drying.

The documented joint/dike fillings in the Injana Formation mimic the sandstone clastic dikes composed of calcite cemented sand-described by Pettijohn (1957) and Marschalko (1978) formed by forcible injection of sand from above or below. The driving mechanism of fissuring has been attributed to earthquakes and the injection of sand to movement of water under hydrostatic pressure. Regarding the Injana counterpart, the features observed are not compatible with the criteria for their recognition.

On the other hand, in calcrete /caliche profiles vertical desiccation cracks (1 m or more in depth) are common features of fluvial deposits, particularly in mudstone (Gierlowski-Kordesh, 1998) and limestone of lacustrine origin (Link and Osborne, 1978), or as fissures caused by enlargement of root traces and vugs by descending water crossing several sequences (Freytet, 1984) or as funnel shaped structures (1-2 m high) filling solution hollows (Knox, 1977). The Injana analog mimics an enlargement of fissures and root traces by acidic pond/lake water moving downward from above; established by the locus of decaying organic matter. This interference is based on tapering downward end of the joints, and the halos resembling iron-rich calcite-spar filled tubules as probable relics of root penetration. In addition the filling of the joint/dike seems to have accumulated as grain by grain embedded in micritic carbonate groundmass with iron oxide stains. This mode can be compared to the initiation of clastic filled dissolution pipes in host limestone imposed by permeable pathway through the clastic cover and/or to concentration of acid water from organic decay in channels/fissures (Walsh and Zacharz, 2001). The fissures, however, may have been initiated as a consequence of differential compaction between the overlying sandstone and the subjacent mudstone, though definite criteria is lacking . Alternatively, a tectonic origin may be invoked, but it seems less likely, due to the long term duration and the punctuation of the sedimentary record which appears discontinuous for short term, thus militate against such an origin, specially when the non-transective nature of the joint to the lower bounding mudstone is considered.

The siltstone-fine sandstone topping the joint filling has a higher content of quartz, iron oxides and pelletoidal mudgrains with unique diatom shell. This perhaps indicates an incipient development of a shallow lacustrine conditions with brackish water in small lake/pond. Reworking of pre-existing calcilithite sandstones of Injana Formation produced loose-reshaped sand grains and micrite mud with marmorization of iron oxides.

In Pliestocene lake Lohantan, backshore pond accumulate diatoms, ostracod and algae between storm events, whereas shoreface deposits are pebble, sand and silt (Blair, 1999).

The interclastic micritic carbonate layer capping the investigated succession is regarded as the product of sublevation of loose-desiccated lake margin carbonate flat with plausible contribution of pedogenic source. Intraclastic carbonate with siltstone-sandstone rich in iron stained calcite has been documented from many ancient siliciclastic-carbonate mudflat of shallow marsh-lake sitting on alluvial plain (Link and Osborne, 1978; Eggleston and Ferdinand, 1990; Gierlowski-Kordesh, 1998; Jo and Chaugh, 2001).

Finally, the sedimentological aspects of this clastic-carbonate package, as a consequence of brief recpites of emersion and submersion, may be considered as a boundary event. In this respect it is correlatable with non-marine carbonate counterpart of Injana Formation documented from other localities (Lawa, 1984). As such, it is worthwhile to ascertain its distribution stillfurther, and to be delineated on a regional scale as an attempt to predict application in sequence stratigraphic study.

CONCLUSION

The siliciclastic fluvial packaging of Injana Formation displays numerous nearly vertical joint/dike in the sandstone layer overlying red mudstone. Their filling consists of detrital sand floating in micritic-microcrystalline calcite stained with iron oxide pigments. These structures are envisaged as enlargement of desiccation cracks, fissures due differential compaction, root traces and permeability pathways by descending water prior or during the establishment of pond/lake between fluvial channels. Assorted vugs lined by microcrystalline calcite and red iron oxides impregnate the texture of the joint filling and the overlying carbonate cemented siltstone-sandstone which contains vestiges of diatom shells-chert spheroids. These features are commonly associated with surface exposure and vadose diagenetic environment with subsequent reworking during flooding events of the interfluvial pond/lake. Intermittent emersion of lake shore carbonate mudflat provided the carbonate clasts, for the top carbonate layer, and their welding was conducive to micritic texture.

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