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The Ussana "Fm": insight about the Sardinian rift from a syn-tectonic unit evolving through space and time

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ABSTRACT - The meaning and the space-and-time variable depositional features of the Ussana "Fm" and of the related coeval units, base of the Late Oligocene - Miocene succession of the Sardinian rift, are discussed. These features, and the presence/absence itself of the Ussana Fm, are related to tectonic and paleomorphologic characters of the Sardinian rift shoulders and their evolution. The features of the Ussana Fm evidence the changing characteristics of the Sardinian rift up to the southern Corsica area. Giving the extremely variable characters of the stratigraphic sections of the Ussana Fm from S to N and also at short distance, a possible lithostratigrahic upgrade of the unit to litostratigrpahic group is proposed.

Keywords: Alluvial deposits; Architectural analysis; Depositional mechanisms; Rift successions; Sardinian Rift.

1. INTRODUCTION

The Ussana Fm (Pecorini and Pomesano Cherchi, 1969) is a dominantly terrigenous continental to transitional stratigraphic unit coeval to and triggered by the opening of the Oligo-Miocene Sardinian Rift (Cherchi and Montadert, 1982). According to Barca and Costamagna (2010), the main rift and the related minor extensional structures (Funtanazza, Cixerri and Giba grabens) were the result of a trans-tensive tectonics connected with the opening of the Algero-Provencal back-arc basin (Orsini et al., 1980). These tectonics led to the development of several pull-apart basins of variable dimensions, showing an half-graben geometry. The Ussana Fm developed as the erosive product of the newly developed relief: it lied down mainly along the eastern edge of the Southern Sardinian Rift (Fig. 1), and so bordering the eastern basement-made mountains of southern Sardinia. The corresponding, thinner Flumentepido Fm, outcropping in the Funtanazza, Cixerri and the Giba grabens of SW Sardinia, seems to show at least partially the same features, being related to the southern edge of the half-grabens. The Ussana Fm (and the Flumentepido Fm) rests unconformably over the former Paleozoic, Mesozoic and Paleogenic lithologies. In its most general stratigraphic setting, it is formed by a fining-upward continental succession built of locally boulder-rich conglomerates passing upwards to sandstones, siltites and finally to fine siltitic - clayey deposits with rare and localized intercalations of carbonates (Casula et al., 2001): these latter mark the passage to the Early Miocene marine transgression represented by stratigraphic units that differ according to the location (e.g. Gesturi Marls, Marmilla Fm). A fan-delta environment for the unit was proposed. The thickness of the unit is highly variable: it may reach 500 m. The age of the Ussana Fm is referred to the Chattian/Aquitanian (Late Oligocene-Early Miocene) based on rare fossil assemblages in its upper part (Pecorini and Pomesano Cherchi, 1969). A detailed study on some outcrops of the Ussana Fm has been carried by Longhitano et al. (2015).

2. VARIABLE GEOLOGICAL FEATURES OF THE USSANA FM IN SPACE AND TIME

2.1. Thickness variability of the unit according to location and tectonic consequences

In the southernmost outcrops the Ussana Fm reaches its maximum thickness (500 m: Dolianova area, Sarrabus; Marcella well, off the Sulcis coast; Casula et al., 2001) and shows a rather marked complexity in terms of sedimentological features and depositional environment. As a general trend, the unit thins out NW-ward until it almost disappears in the Ottana graben area (central Sardinia), where the base of the rift succession is represented by pyroclastic and/or epiclastic deposits. But clastic or mixed deposits referable for stratigraphic position to the Ussana Fm are still locally and limitedly visible northward, as are sometimes significant accumulations at the base of

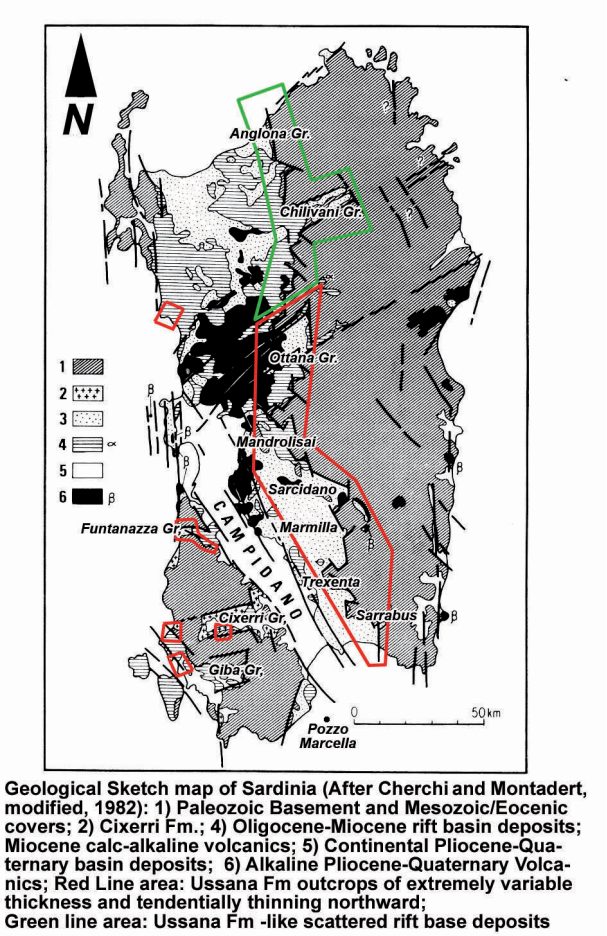

Fig. 1 - Sardinia sketch map: distribution of the Ussana Fm-like outcrops.

the rift succession (e.g. Anglona, Chattian: Tergu Fm, Sowerbutts, 2000). Conversely, in the mirroring and close southern Corsica area (Bonifacio Basin: Tomassetti et al., 2013) rarely Burdigalian coralline bioconstructions may rest unconformably over the granitic Variscan basement through a thin accumulation of mixed clastic and carbonate debris: otherwise, more commonly, the bioconstructions encrust and grow directly over the granite.

Nonetheless, from the SE Sardinian rift extremity and heading in the NW direction, in the Sarrabus, Trexenta, Marmilla and Sarcidano areas the thickness of the Ussana Fm is frequently subject laterally to sudden and dramatic reductions and thickening, thus passing from hundred of metres to a couple of tens of metres of conglomerates and sandstones resting over older deposits (usually Variscan metamorphics) and vice versa. This behaviour is due to fault lines systems crossing at right angle (subordinated and NE/SW-oriented with the main NW/SE Sardinian Rift faults): during the development of the rift they determined alternated consecutive areas of strong and weak subsidence (piano-key tectonics) (Fig. 2). In the strongly subsiding areas fan deltas accumulated expanding towards the central rift area: they formed thick but short depositional systems which passed upwards and seaward quickly to the Miocene marine successions. Conversely, in the slowly subsiding interposed areas the sedimentation started later, following the deliberate lateral coalescence of different fan-delta bodies, and was then featured by thin accumulations of fossiliferous conglomerates and sandstones. They were soon reworked by marine processes. This thinner, transitional succession, variously referred on occasion to the Ussana Fm or to the Gesturi Sandstones (Cherchi, 1985), has been recently designated as Nurallao Fm (Funedda et al., 2007): it represents the passage to the Miocene marine succession of the Marmilla Fm.

Other outcrops referred to the Ussana Fm exist: they are located far from the edge of the Sardinian rift, in inner areas of Eastern Sardinia (Sarcidano, Gerrei): here the extensional tectonics triggered small graben (half-graben?) structures whose bearings of the main tectonic lines corresponds to the bearings of the master faults of the Sardinian rift. They were filled by fining-upwards continental alluvial fan to fluvial successions but they never experienced marine sedimentation due to their sheltered and/or elevated position located in the middle of the emerged Variscan basement.

2.2. Sedimentology and depositional mechanisms

The limited lateral persistence of the outcrops of the Ussana Fm in single sectors does not allow the reconstruction of a complete fan delta body: it is only possible to point out different sub-facies in diverse fan delta aligned along the irregular eastern border of the Sardinian rift.

In the Sarrabus outskirts area the unit outcrops are thickest and are featured at its base by a variable amount of eluvial deposits. They are covered by alluvial fan delta deposits (red bed facies), in their turn followed by transitional to marine sediments. At Sinnai and Sa Frissa (Serdiana, Southern Sardinia) quarries fronts show often, unconformably posed over the Variscan magmatites, a chaotic, very coarse matrix-supported slope megabreccia formed by polygenetic cobbles and boulders up to metric in size, embedded into a conglomeratic matrix. This deposit, interested by sinsedimentary faults and unconformities, represents likely the prime alteration product of the Variscan Basement during the Late Oligocene, and the start of the Ussana Fm. The basal slope megabreccia at Sinnai is followed by coarse conglomerates deposits of probable sheet flood origin. They also often show internal unconformities and evidences of sinsedimentary tectonics. Their thickness is never more than 15 m.

In the Trexenta area (Monastir), along the front alignment of the Is Serras, Francischettu and Sa Cenobita quarries directed NNW, the Ussana Fm. lies down paraconformably to unconformably over the Cixerri Fm (Middle Eocene-Early Oligocene: Pecorini and Pomesano Cherchi, 1969) and its base misses of eluvial deposits. In the Is Serras quarry front, at most 20 m high, the base of the Ussana Fm is built of reddish, conglomeratic sheet floods that evidences in their upper part some possible

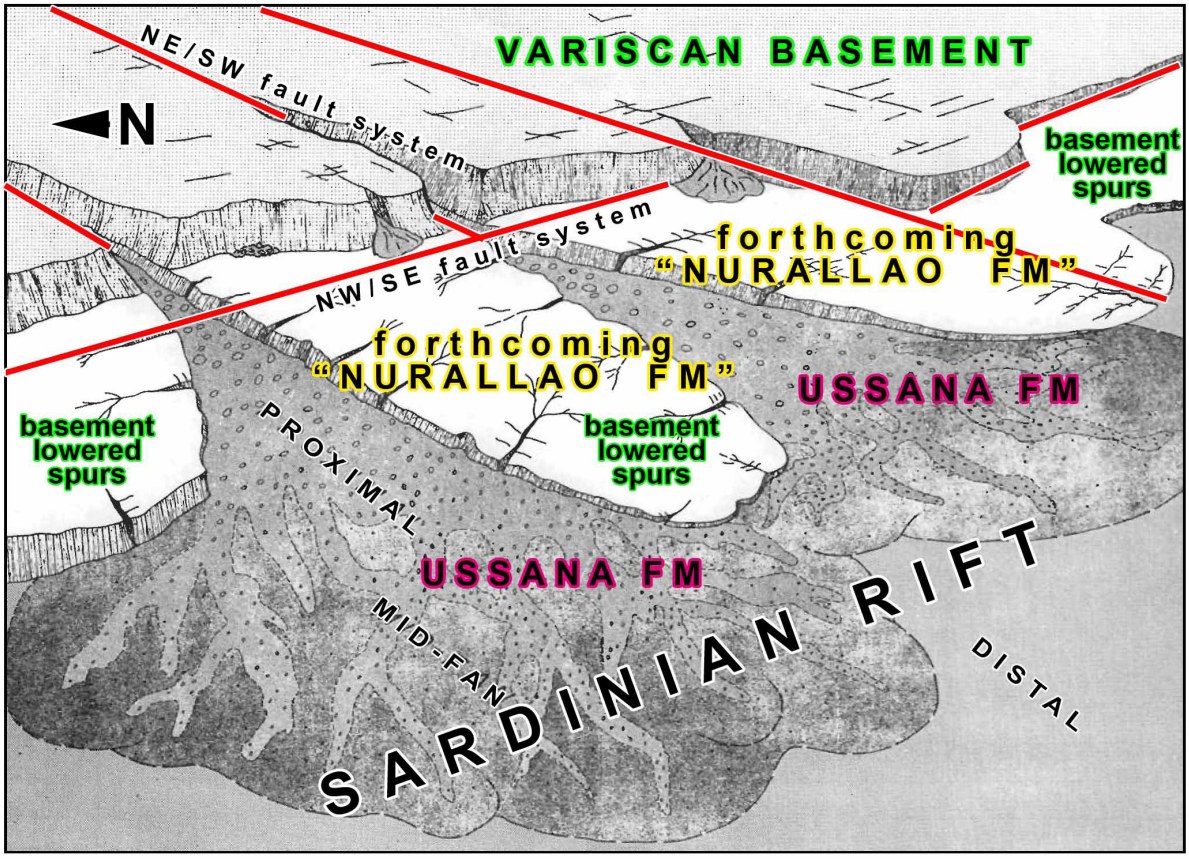

Fig. 2 - Depositional sketch and setting of the Ussana Fm in the frame of the Sardinian rift eastern edge.

sinsedimentary intraformational unconformities, maybe linked to slope acclivity variations. The related boulders-rich poorly-bedded conglomerates are constituted by the superposition of gravel bars. Rare, interposed clayey-siltitic lenses due to stops of deposition and rare massive flows linked to storm events are also present. In the N-ward Francischettu Quarry front, more than 30 m high, a similar situation exists: well-developed reddish conglomeratic sheet flows forming gravel bars intercalated with minor silty beds cover paraconformably the Cixerri Fm: here the transition from the lower to the upper unit looks less sharp. Further to N, along the Sa Cenobita quarry fronts, an upper part of the Ussana Fm is also visible, and the sedimentation pattern starts to change: here, over the conglomeratic gravel bars, usually massive silty-sandy intercalations, grayish to purple in colour and gradually converting from lenticular to tabular in shape, firstly appear and afterwards spread towards N. They gradually prevail over the conglomeratic-sandy bodies, in their turn shifting progressively from a tabular- to lens-shaped, and so passing to channelized, multistorey bodies.

In the Marmilla area (Sanluri), new motorway roadcuts through the Ussana Fm. evidenced some conglomeratic to silty-clayey outcrops easily correlatable each other. Scarce volcanics are intercalated. The stratigraphic sections on the whole are not more than 50 m thick but the depositional bodies can be plainly followed by side. They are formed essentially by conglomeratic sheets, ribbons and lenses embedded into silty-clayey deposits. The conglomeratic fills of the single-storey channel are fining-upward deposits less than a meter thick and not more than 10 to 12 m wide. They are usually gravel bars whose erosional depressions are filled by minor sandy bars: rarely the sandy bars may take place directly on the channel bottom. Rare crevasse splays are present. These bodies may show lateral migration evidences and were deposited by stream flood processes. Scattered synsedimentary faults have been observed. In the upper half of the succession, some coarse events, laterally extended (at least over 150 m wide), more than 5 meters thick occur: they are formed by cobbly conglomerates with tabular shape and a faint fining-upward trend intercalated by waning-waxing structure. They are the product of a sheet flood resumption. This passage from scattered ribbon-shaped bodies to extensive, thicker tabular bodies towards the top of the section could suggest the shift of a main depositional lobe along the alluvial fan surface (autocyclic processes), a renewing of the tectonic activity (allocyclic process), or perhaps both.

In the Mandrolisai area (Allai), over the Variscan basement the Ussana Fm is featured first by a thick succession of chaotic boulder-rich conglomerates and rare sandstone beds built of superposed, amalgamated events due to debris flows. Upwards, the unit passes again to organized conglomerates deposed through sheet

floods and organized as gravel bars.

In the Ussana Fm both massive and tractional processes have been identified as depositional mechanisms: the firsts are mainly confined to the inner part of the fan and in the lower part of the succession: they are related to stronger relieves and higher slopes.

2.3. Stratigraphic considerations

The Ussana Fm, although referred to a single stratigraphic unit, actually designates instead a group of units unconformably resting over older rocks, and related to the first opening of the Sardinian rift and related structures in the Late Oligocene-Early Miocene. Even though the stratigraphy of these units look similar each other, they are connected to different sedimentary contexts and follow diverse evolutionary paths: the Ussana Fm sections that are lined up along the eastern slope of the Southern Sardinian Rift differ from each other along the eastern fault of the Sardinian rift. They differ more from the sections in the Funtanazza, Cixerri and Giba grabens and even more from the Ussana Fm deposits cropping out in the internal depressions of the Sardinia Eastern Variscan horst, even if they are related to the same age and extensional context. In detail, the Ussana "Fm" cropping out along the border of the rift is a succession of variable thickness and sedimentological features according to the diverse tectono-stratigraphic context it laid down. Thus a stratigraphic re-organization giving to the unit a higher lithostratigraphic rank should be advisable.

3. DISCUSSION AND CONCLUSIONS

The variable, N-ward gradually reducing thickness of the terrigenous erosive Ussana Fm at the base of the Sardinian rift succession should have precise meanings: it may reflect a less marked importance and a diverse timing of the rifting processes, a less pronounced relief and, possibly, a minor and slower subsidence of the entire extensional system in that direction. The diffuse presence of the unit only along one margin of the interested tectonic structure and the diverse morphotectonic features of the two edges themselves (Casula et al., 2001) suggest a pull-apart opening mechanism and an half-graben structure (Christie-Blick and Biddle, 1985).

The investigated outcrops figure out spots in which are represented different alluvial fan sub-environments (Fig. 3): inner fan (Allai, Sinnai, Sa Frissa, Monastir southern area) featured by dominant sheet floods over debris flows; middle to outer fan (Monastir northern area, Sanluri) represented by gradually increasing ribbon-shaped channelized stream food incised into overbank deposits. The mean grain size both of the whole deposits and of the single channelized bodies decreases towards the outer environments. The base of the fan is often marked by megabreccias or colluvial deposits, as in the Sa Frissa and Sinnai quarries. These data, joined with the presence of gradual, alternate passages with sharp energy variations to the marine realm (conglomerates, sandstones and calcarenites) towards the top of the succession, confirm the lower and middle part of the Ussana Fm deposition took place into different subenvironments of several fan-deltas lined up along the eastern border of the Southern Sardinian Rift, possibly forming a bajada belt at least at some point of their history.

The Ussana Fm and the Nurallao Fm represent the same pattern of sedimentation and similar depositional environments: their differences lay in the fact that are only partially coeval, they show different thickness, and they deposed over differently subsiding tectonic blocks. So they should be merged and considered members of the same lithostratigraphic unit.

Based on currently ongoing investigations along

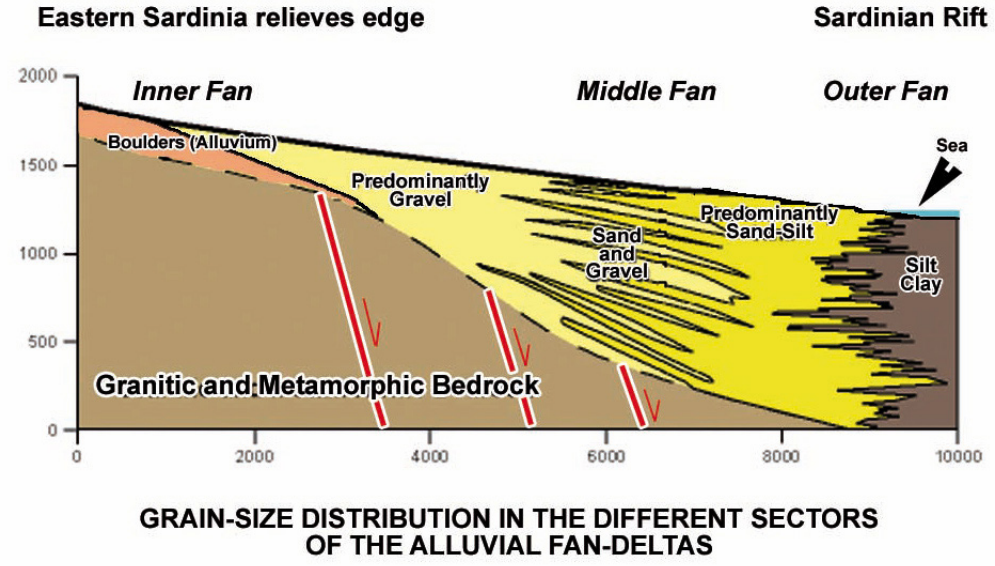

Fig. 3 - Fan delta scketch in the Sardinian rift.

all the Sardinian Rift, instead of a single Ussana Fm, a more articulated reference frame of this unit may be here suggested. It is proposed that every local unit (also named accordingly) will be identified by stratigraphic-depositional criteria. Thus, an "Ussana Group" representing a basal terrigenous, continental tectonofacies due to the opening of the Sardinian Rift in Late Oligocene-Early Miocene, will achieve a specific tectono-sedimentary meaning.

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