Sedimentary breccias formed during extensional tectonics: facies organization and processes

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A breccia is a rock made up of angular clasts. Its formation can be the result of several types of geological processes (sedimentary, tectonic, hydraulic, etc...):

In this study, we are trying to understand the formation and the preservation of sedimentary breccias with a significant thickness (several tens to hundreds of meters) in extensional environments, by comparing:

- **1 - Crete**: recent analogue; Pleistocene-Holocene deposits of the Chora Sfakion region, SW coast Crete.

- **2 - Pyrenees**: old geological system; the Bas-Agly Basin, in the eastern French Pyrenees.

*In both cases, the breccias consist mostly of carbonate clasts.*

The different geological processes responsible for the formation of breccias in extensive setting. *(kernif et al., in prep)*
Sedimentary (or depositional-breccias)

In this study

Environmental setting of depositional carbonate breccias. A: Cross section from land – to platform and platform margin with reefs – to slope and deep swells – down to deep-water basin. B: Cross section across a distally steepened ramp.

(Flügel, 2010)
- **Lefka Ori Mountains**: Late Eocene to early Oligocene thrust-pile
- Lower metamorphic units (HP/LT) and upper non-metamorphic units
- Crustal extension in the N-S direction
- Three major fault segments

**Sfakia Fault:**
- A steep south-facing escarpment
- Dip: 70°–75°
- Extends on ~16 km
- Formed during the Early Pliocene

**Piedmont "Sfakion":**
- 1.5 to 2.5 km wide
- Formed by multiple coalescent fan complexes (alluvial-fans deposits)
Nemec and Postma (1993) distinguished three main sedimentation stages during the development of the fans (see also Pope et al., 2008, 2016):

i) during **Stage 1**, angular debris-flow deposits built small fans with depositional slopes of 20-22°. The highly immature debris are viewed as derived locally through headward erosion of mountain-front ravines;

ii) during **Stage 2**, streamflow deposits built a stack of large fan lobes which represent the bulk of the piedmont alluvium;

iii) **Stage 3** is represented by minor Holocene unconsolidated gravels attributed to ephemeral stream-flood surges.

In this study, we present a re-investigation of Stage 1 deposits as far east as the Aghios Nektarios Fan.
Two sets:
- A first set of breccias constituted mainly black dolomitic elements with grain size varying from clay to coarse sand
- The second set corresponds to a polygenic breccia, essentially composed of metamorphic elements of phyllite-quartzites and various carbonate debris overlain in unconformity by poudingues facies (pebbles to cobbles size)

Stratigraphic column of the study area (Anghios Nektarios valley) in southwestern Crete. (kernif et al., in prep)
- The footwall of the normal fault is uplifted while the hanging wall of the normal fault subside allowing a progressive growth of a relief

- The important local relief becomes unstable, collapses and produces major rockfall

- This process is active all along the movement of the normal fault

- The breccia succession shows in the first clasts derived from the upper unit (TPU) and then clasts of the other units appear progressively...
A) Structural sketch map of the Pyrenean range simplified after the BRGM 1/1000,000 geological maps (IMZ: Internal Metamorphic Zone and Peridotite from Clerc, 2012).

B) Simplified geological map of the study area modified after the BRGM 1/50,000 geological maps of Tuchan (Berger et al., 1997); Perpignan (Berger et al., 1988); Leucate (Bles and Berger, 1982); Quillan (Crochet et al., 1989) & Rivesaltes (Fonteilles et al., 1993).

C) Geological cross-section of the study area

- The sedimentary breccias of the Bas-Agly Basin are found on both sides of the Bas Agly syncline and have been observed in the quarries of Baixas in the South and Vingrau in the North.

- North South geological cross-section of the Bas Agly syncline shows the outcrop zones of the “brèche limite”, located at the Late Jurassic-Early Cretaceous boundary.
A. Geological cross sections through the eastern part of the North Pyrenean Zone (NPZ) illustrating the Bas Agly syncline and the location of the study breccias. B. Stratigraphic column of Baixas quarry (Baixas, south flank of Bas Agly syncline). C. Stratigraphic column of Coume Roujou quarry (Vingrau, north flank of Bas Agly syncline). (kernif et al., in prep)

Three principal facies sets

(i) fine limestone and dolomite facies typical of Middle to Upper Jurassic carbonate platform,

(ii) a large mass of polygenic breccia up to 250 metres thick with locally some fine-grained limestone intercalations,

(iii) white limestones rich in rudists typical of the Urgonian facies, i.e. Lower Cretaceous shallow-water carbonate platforms

This system present comparable characteristics to those of Crete:

- Normal Faults;
- Angulous clasts of various size;
- Upward coarsening;
- Clasts are of various colours mainly carbonate and the proportion of each type is variable for each breccia layer depending on the source;
- Rockslide (Internal gliding)
The sedimentary process is the same than for Crete
The breccias deposits result from sedimentary processes related to rockfall and rockslide dynamic, with creation of a relief which becomes very important, unstable, collapses and produces major sedimentary breccias deposit in a extensional basin where limestone are deposited.
In general, in the extensive system, like a rift, at the beginning of extension the rivers flow in opposite direction of the rift, and watersheds oriented towards the rift are very small or nonexistent, so along rift borders mass transfer is related to collapse processes and rockfall that dominate towards the basin.

These breccias are deposited at the beginning of the deformation in extension, which provide parameters necessary to produce and preserved sedimentary breccias that is to say: i) footwall uplift, that create important topography, ii) hanging wall rapid subsidence, iii) topography collapse in direction to the base of the slope of the normal fault, iv) rapid preservation to avoid clasts reworking by drainage system.

So sedimentary breccias correspond to syn-tectonic deposits during the first stage of extensional basin formation that favors both the creation and preservation of sedimentary breccias.
Thank you for your attention

Any Questions?
Do not hesitate to contact me!
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References


