

Further contributions to a new tectonic interpretation of the Sainte Victoire Mountain (Provence, France)

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ABSTRACT

A new tectonic interpretation of the Sainte Victoire Mountain (north of Marseille, south eastern France) is proposed, principally invoking vertical movements and providing evidence which suggests an uplift which may be still active today in the western part. Some new observations confirm our hypothesis.

Key words: Provence, tectonics, faulting, Sainte Victoire, France

Contribuciones adicionales a una nueva interpretación tectónica de la montaña de Sainte Victoire (Provenza, Francia)

RESUMEN

Proponemos una nueva interpretación tectónica de la montaña de Sainte Victoire (norte de Marsella, sureste de Francia), en lugar de hipótesis más antiguas que estaban basadas en interpretaciones tectónicas raras. Invocamos principalmente movimientos verticales y proporcionamos evidencia que sugiere un levantamiento tectónico que puede estar activo en la actualidad en la parte oeste. Algunas observaciones nuevas confirman nuestra hipótesis.

Palabras clave: fallas, Francia, Provenza, Sainte Victoire, tectónica

VERSIÓN ABREVIADA EN CASTELLANO

Introducción y metodología

En las últimas décadas se ha apelado a un cabalgamiento del norte hacia el sur para explicar la posición dominante del Jurásico de Sainte-Victoire, en comparación con los terrenos secundarios y terciarios situados al sur (Corroy G. et al. 1964, C. Tempier 1987). En 2005, propusimos (J. Ricour et al., 2005) una nueva interpretación, que atañe principalmente a los movimientos verticales y proporciona elementos que permiten suponer un movimiento de elevación que aún continúa, al menos en la parte occidental de la montaña.

Esta nueva hipótesis fue motivada por varias observaciones:

- De lejos, Sainte-Victoire aparece en el paisaje como una barrera (del Jurásico e Infra-Cretácico) que domina casi 1000 m del sinclinal de Cengle (Terciario) y la llanura de Arc (Secundario);*
- La morfología de la parte occidental de la barrera, que se interrumpe bruscamente al oeste, tiene una apariencia joven que recuerda a un paisaje alpino. Hacia el este, a pocos kilómetros, esta morfología y altitud se atenúan rápidamente;*

- De cerca, sobre el flanco meridional de la parte occidental de Sainte-Victoire, se observan grandes superficies subverticales talladas en la caliza mesozoica, estriadas, en contacto con una brecha de elementos fini-cretácicos y terciarios, a los que nos referimos con el término de “complejo de Tholonet”, que es transgresivo y discordante sobre el Mesozoico;
- Durante la publicación de estas notas en 2005, nos beneficiamos de los resultados de una interferometría de radar de precisión por satélite, realizado durante el período 1993-2003. De acuerdo con este estudio, el extremo oeste de Sainte Victoire, y sólo él, ha sufrido durante este periodo una elevación de más de 7 mm por año.

Discusión y conclusiones

En 2005, demostramos en la parte suroeste de la cadena, la brecha transgresiva sobre las calizas cretácicas y jurásicas, pero verticalizadas (Fig. 3 de la nota de 2005 y reproducidas aquí en las Fig. 2a y b). Nuestras nuevas observaciones, las cuales cubren todo el lado oeste de la cadena, muestran las fallas de sustentación vertical, con jirones de brecha transgresiva también verticalizados. Esto es bien visible en los lugares marcados con una flecha roja en la Figura 1, al norte y al noreste de la cabaña Cézanne. Estas nuevas observaciones muestran la interpretación tectónica clásica propuesta, y utilizada en el mapa geológico 1:50000 (hoja d'Aix en Provence), se ha de rectificar pues muestra una fragmentación en unidades cabalgantes, a veces hacia el norte, a veces hacia el sur, sin tener en cuenta el carácter polifásico de esta construcción tectónica (del Albiense al Mioceno) y hechos observables sobre el terreno. Las observaciones mencionadas anteriormente, inducen a repensar la interpretación clásica sobre el suroeste del macizo de Sainte Victoire porque es cabalgante hacia el sur o hacia el norte su prolongación meridional y occidental estaba oculta por el juego de fallas más recientes (Maestrichtiense a la actualidad).

Introduction

When approached from the south, from roughly 12 kilometres east of Aix-en-Provence, the Sainte Victoire Mountain appears as a wall of white, mainly Jurassic, limestone, surging from the earth (“like a ghost ship” as Jean Giono might have said), dominating the Cengle Plateau Anticline and the Arc Plain. Curiously this wall stops suddenly to the west, which on a first impression would suggest the presence of a tectonic feature. Another curious feature is that, if the western part is reminiscent of a young mountain, evocative of strongly-eroded alpine topography, the apparent age of the mountain appears to increase to the east as its altitude diminishes. Since the publication of the 1:50000 scale geological map for Aix en Provence, various structural interpretations have been proposed. As a result of our recent observations in the field new evidence has emerged defining the role of tectonic events subsequent to the deposition of the terminal Cretaceous sediments, and of the Tertiary breccias, which we will refer to below as the “Tholonet Complex”. This group is transgressive on, and discordant with, the Mesozoic. This paper, similarly to the previous one (J. Ricour *et al.*, 2005) will not address the Mesozoic framework of the massif, but rather discuss the later events which further complicated it.

The Tholonet Complex, in successive tectonic interpretations.

Since 1964, a thrust from the north towards the south was invoked to explain the position of the Sainte Victoire mountain (G. Corroy *et al.*, 1964, C. Tempier 1987). According to recent research (S. Leleu 2005), this thrust involved a series of alluvial cones, dating from the Santonian to the Paleocene and precursors of middle Eocene thrusting. This alluvial group, which we will refer to as the “Tholonet Complex”, is mainly composed of breccias and conglomerates.

In 2005, in view of observations in the field, and particularly of sub-vertical faults, which constitute



Figure 1. Locations of the new observations (Fig. 2a, 2b and 3) on ortho-rectified aerial photographs.

Figura 1. Localización de las nueva observaciones (Fig. 2a, 2b y 3) sobre fotografías aéreas ortorectificadas.

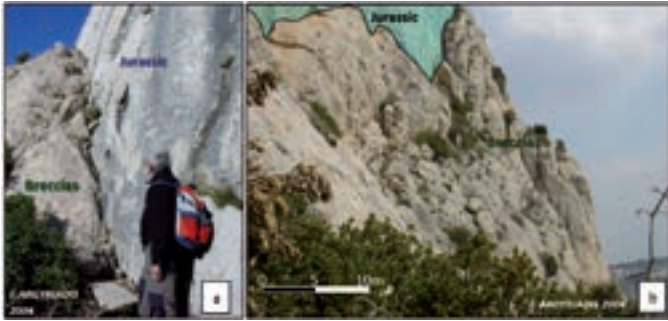


Figure 2. The Saint Victoire Mountain South Face vertical fault. A) looking to the north-west. B) looking towards the south-east.
Figura 2. La falla vertical de la cara sur de la montaña Sainte Victoire. A) Mirando hacia el noroeste. B) Mirando hacia el sureste.

the limit of the western part and to the south, we proposed a new interpretation of this sector (J. Ricour *et al.*, 2005) based essentially on vertical movements, and in view of the pristine nature of the topography, proposed that this uplift is recent, so much so that the results of a satellite radar interferometry study carried out during the period 1993-2003 suggests that the western part of the mountain range has undergone rapid uplift during this period.

In 2013, during a meeting of la Société géologique de France in Provence, N. Espurt led a day-long excursion in the Sainte Victoire region. During this, he presented cross-sections (N. Espurt 2013) showing an overturned syncline of breccias on the western

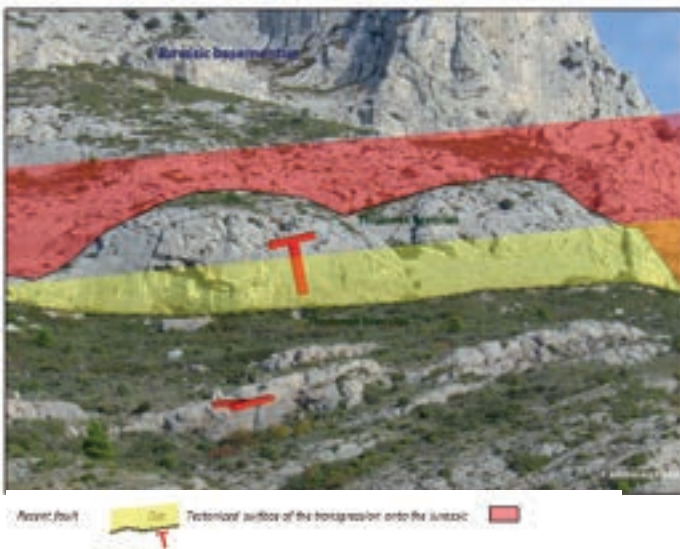


Figure 3. The West Face of the Sainte Victoire Mountain: The Tholonet Breccias fractured and verticalized against the Mesozoic framework.
Figura 3. La cara oeste de la montaña Sainte Victoire : Las brechas Tholonet fracturadas y verticalizadas frente al marco Mesozoico.

face of the Sainte Victoire mountain (N. Espurt 2013, Livret guide Fig. 8, p. 51).

New observations

This interpretation, proposed by F. Touraine (1973), is an optical illusion resulting from a long focal lens bringing together two objects, in fact several hundreds of metres apart and separated by an approximately vertical fault. Similarly his interpreted cross section of the south flank of the Sainte Victoire mountain (Fig. 7, p.50), shows sub-horizontal thrusts substituted for sub-vertical faults (Figs. 1 and 2a above) which can be easily seen (Fig. 2b above). J. Ricour *et al.* 2005 state that the breccia and its immediately underlying basement are transgressive on the lower Cretaceous and Jurassic limestone of the mountain, and that this transgressive group has been verticalized along the cliff of the south-west corner of the range. We have now observed the same phenomenon on the western flank. This “verticalization” is, of course, accompanied by fractures between the region in close proximity to where the breccia is only dipping or folded, and its vertical section (Fig. 3). Such fractures are obvious in the whole sector between the Refuge Cézanne and the Pas de l’Escalette (Fig. 1).

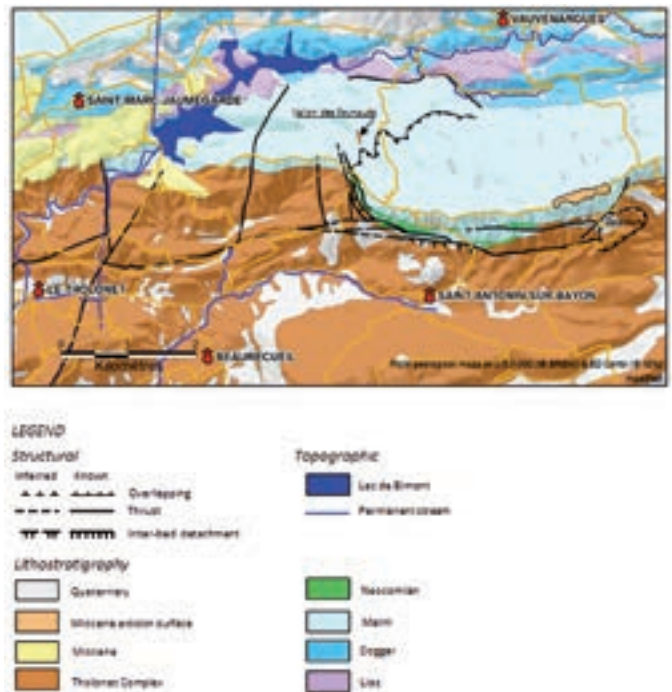


Figure 4. Simplified geological map from Sainte Victoire.
Figura 4. Mapa geológico simplificado desde Sainte Victoire.

Conclusions

The formation of the mountain and its present relief seems to have followed the following chain of events:

- The Bimont anticline, which is part of the Saint Victoire mountain and with which it is in lateral continuity, develops, probably from the end of the Upper Cretaceous (post-Fuvélien). It folds as it rises and supplies the Tholonet Complex breccias with sediment.
- The final phase of its uplift is the origin of the accentuation of the *pro parte* synsedimentary dips of the breccias, in particular on its southern flank.
- After the Oligocene the NNE-SSW network of faults of the middle Durance becomes active, causing, amongst other things, and locally, dislocation and the "piano key" uplift of the western part of the Sainte Victoire mountain.
- This movement, which is controlled by a network of a "scissored" combination of faults, dies out quickly to the north, but also to the east. In a final phase, these faults are cut again and blocked by the E-W fault system which shapes the southern face of the mountain.
- This movement is active again from the Post-Miocene (C. Rousset 1967) to the present day. The uplift of the limestone mass feeds, by rock slide amongst other things, the breccia unit of the Oppidum (Fig. 4 below).

On the back of this limestone mass, on a vertical ridge dominating the right bank of the Reynauds Valley, is a fragment of red detritic sediments belonging to the Tholonet Complex. This outcrop is included in the 1:50 000 geological map, but incorrectly interpreted as allochthonous. In fact it is simply transgressive, and is further proof of the absence of thrusting onto the breccia. In the heart of the massif there are certainly tangential tectonic pre-breccia events, but the existing data is insufficient to permit a coherent analysis. There is also folding and minor thrusting within the Tholonet Complex itself (for example the Torque Syncline), but it is the recent uplift of the massif which has detached and thrown off its covering that has caused these deformations. The tectonic interpretation traditionally proposed, and that was applied to the 1:50 000 geological map (Aix en

Provence sheet), is underpinned by a fragmentation of allochthonous units, thrust sometimes towards the North, sometimes towards the South. However the episodic nature of these tectonic events (from the Albian to the Miocene) and the facts laid out above, lead us to revise this classic interpretation, which does not include the many tectonic episodes, and, for the region studied, does not take into consideration the field observations. In particular, the use of balanced sections does not appear to be well adapted to Provençal units, the variations of which depend on their sedimentology, tectonics and erosion.

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