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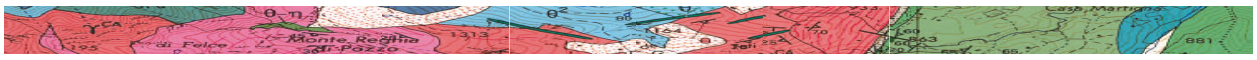

Integrated geophysical and geological modelling: insights in the 3D structure and kinematics of the Hercynian Suture Zone in the Champtoceaux area (Brittany, France)

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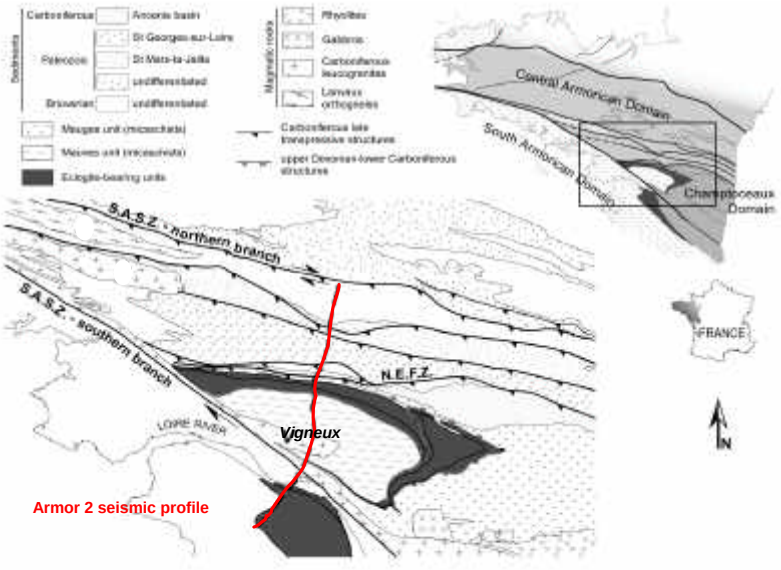
ABSTRACT

Using the Editeur Géologique, a software specifically developed for the purpose of 3D geological modelling by the French Geological Survey (BRGM), we model a segment of the Hercynian suture zone of western Europe, in Champtoceaux area (Brittany, western France). The area shows exposures of strongly deformed eclogite-bearing gneisses and micaschists. These units were stacked during collision and exhumed during late Devonian to early Carboniferous times. Regional-scale dextral simple shear accompanied strike-slip movements along the SASZ (South Armorican Shear Zone). It produced a km-scale antiformal structure in the Champtoceaux metamorphic units with a steeply-dipping axial plane and a steeply eastward-plunging axis. Interpretation of the recent Armor2 seismic profile shows that the well-recognized north-dipping early lithological structuration is cross-cut by Carboniferous south-dipping inverse tectonics of crustal extension. In order to precise and extend in 3D the structures interpreted in the seismic profile, we model seven radial gravity profiles throughout Champtoceaux periclinal termination, based on data from the French gravity database. Direct 2D modelling is performed at a crustal scale, based on seismic constraints and geological field observations, as well as density measurements on samples or in drill holes. Input in the Editeur Géologique, the consistency of cross-sections, digitized geological map and structural information (foliation dips) is first checked. From the surface to the Moho, available spatialised 2D information is then interpolated in the whole 3D space using adapted geostatistical analysis. Finally, taking into account densities associated to each modelled geological body, the computation of the 3D gravity effect of the model is compared to the measured Bouguer anomaly, which insures that all complex 3D gravity effects are well taken into account. Results emphasise the usefulness of integrated geological and geophysical 3D modelling for the interpretation of crustal-scale tectonics and kinematics. Important geological results derived from this modelling are: (i) the 3D imaging of the south-dipping thrust band interpreted in the seismic profile; its compatibility with a kinematic model in which the folding of the Champtoceaux metamorphic complex and global thrust movements toward the north during late strike-slip movements along the SASZ are contemporaneous, (ii) the relatively shallowly rooted character of the northern limb of Champtoceaux anticline, a feature which was not expected from geological data, (iii) the 3D shape of granitic massifs sheared along the SASZ strike-slip: Vigneux syntectonic leucogranite rooted in the southern branch of the SASZ down to about 10-15 km and spread in subsurface, in the core of Champtoceaux arc, and Lanvaux orthogneiss, elongated along the hanging wall of the south-dipping thrust for more than 150 km, in subsurface as well.

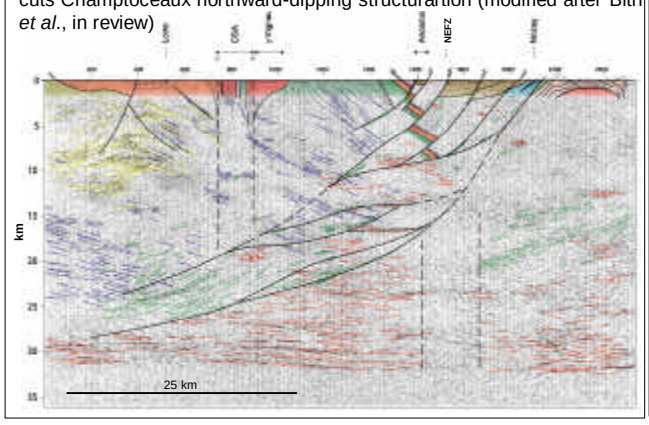
GEOLOGICAL SETTING

Simplified geological map of the Champtoceaux area in the Hercynian belt of Britanny (France). SASZ, South Armorican Shear Zone; NEFZ, Nort-sur-Erdre Fault Zone.



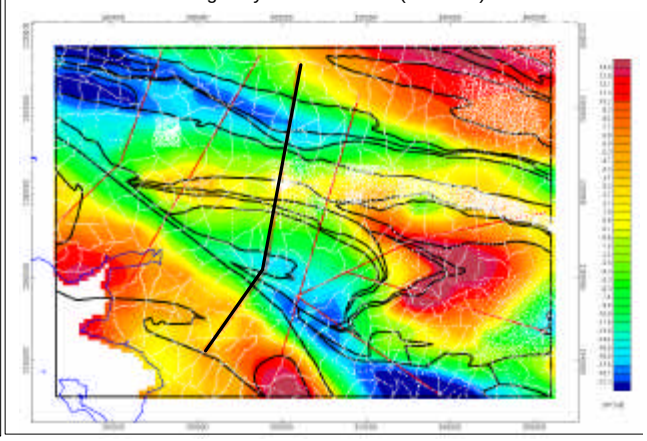
ARMOR 2 DEEP SEISMIC PROFILE

Interpretation of Armor 2 seismic profile (located on the geological map) shows an unexpected south-dipping crustal-scale structure that cross-cuts Champtoceaux northward-dipping structurartion (modified after Bitri *et al.*, in review)



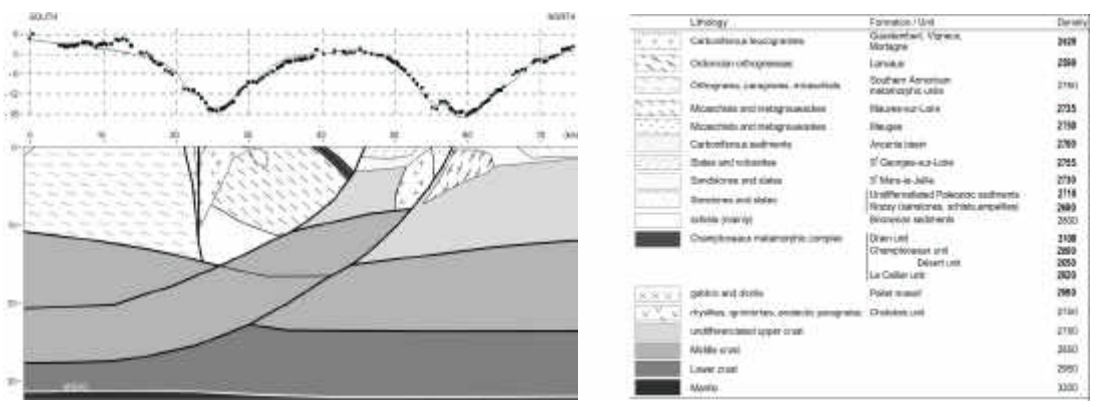
BOUGUER ANOMALY MAP

Gravity data (white dots) and anomalies in the Champtoceaux area. Location of the seven gravity cross-sections (red lines).

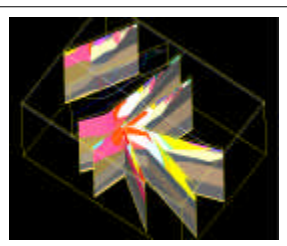


2D GRAVITY MODELLING

The Bouguer anomaly has been modelled along 7 cross-sections (using Geosoft-GmSys software). Here we show the profile located along Armor 2 seismic line. Seismic interpretation constrains the deep interfaces in the gravity model.



3D INTEGRATION

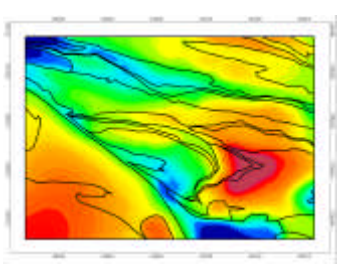


• Insuring 3D coherency
• Revision of the 3D interpretation

1

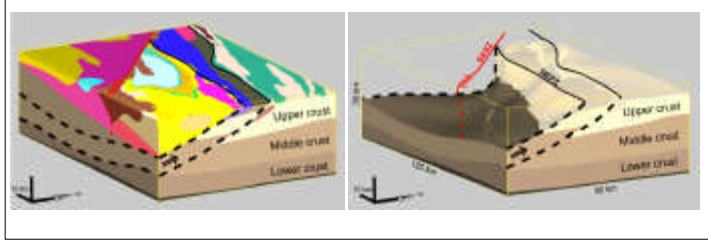
2

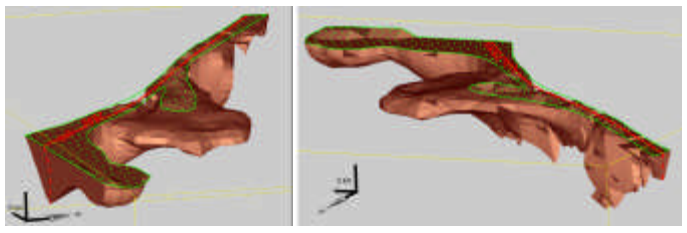
Comparison between the Bouguer anomaly and the computed 3D gravity effect of the model



INSIGTHS IN THE 3D GEOMETRY AND KINEMATICS OF CHAMPTOCEAUX COMPLEX

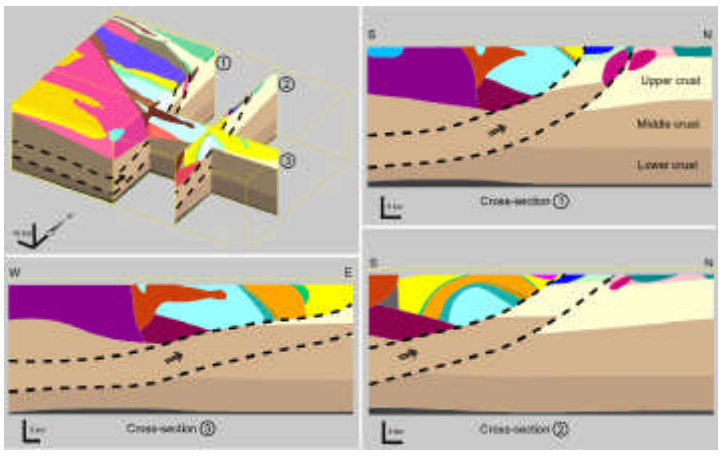
3D view from the SE of Champtoceaux area (left) and of middle to lower crustal interfaces beneath the Champtoceaux complex (right). Black-dotted lines highlight the south-dipping crustal-scale shear zone. This structure becomes sub-vertical at the vicinity of the SASZ. This is consistent with regional kinematics model involving folding of the Champtoceaux metamorphic complex and its northward thrusting during late strike-slip mouvements along the SASZ (Bitri *et al.*, in review).





Views from the SE (left) and NW (right) of Vigneux leucogranite (see location on the geological map). Green lines are limits of the granite at the surface. Modelling suggests that the granite is sheared and rooted along the SASZ (red line) down to about 10 to 15 km. In the core of Champtoceaux complex, the gravity modelling attests that the granite spreads into a laccolith, mostly in sub-surface. This shape is in accordance with the results of analogue experiments that modelled upper-crustal synkinematic intrusions emplaced away from strike-slip zones within weak country rocks (Roman-Berdiel *et al.*, 1997).

Example of cross-sections extracted from the 3D model, outlining the 3D folded shape of the Champtoceaux complex (in orange and blue) above the crustal-scale shear zone (black dotted lines).



CONCLUSIONS

Methodology :

• Reassesment of the need of combined geology-geophysics-based approaches to understand crustal-scale tectonic processes.

• 2D geophysical and geological data are processed together in the Editeur Géologique and interpolated to the whole 3D space. Refinements can be introduced interactively to insure the consistency between data, so that a relevant 3D geometry can be produced.

• Compatibility of the 3D model with the geology, the seismics, and, *a posteriori*, with the measured gravity anomaly.

Geology :

• The primary geometry of the Hercynian suture zone of Britanny is obliterated by a late E-W striking thrust system that brings the Champtoceaux Domain on the southern part of the Central Armorican Domain.

• The south-dipping wrench-thrust system becomes vertical toward the West, where approaching the SASZ. This is kinematically consistent with thrusting along the northern boundary of the Champtoceaux Domain and wrenching along the SASZ.

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