

Interactive comment on “Evolution of the Iberian Massif as deduced from its crustal thickness and geometry of a mid-crustal (Conrad) discontinuity” by Puy Ayarza et al.

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This paper presents and interprets a composite seismic profile and that images the crust and upper mantle across the Iberian peninsular. It's an interesting topic: it is likely to have broad appeal beyond the immediate communities working on tectonic problems in this part of Europe. But as a contribution for the Special Issue - the topic is ideal. The authors are to be commended in showing the seismic images in both un-interpreted and interpreted form. However, it is to be hoped that the clean versions will be made available in large format, beyond the limitations of the standard publication. . . The manuscript is generally well-written – although there are a few glitches (some

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of which are picked up in the points below). The use of information of WA seismic experiments – to better constrain velocities, and “normal incidence” records (for reflections) is commendable. It’s good to see a well-documented seismic processing workflow. Discussion of the challenges of merging imagery from different experiments is rather brief (Section 3.2) but the points are well-made. This is a non-trivial task, especially given the experiments were in different tectonic domains, with distinctly different near-surface geology. This of course makes it difficult to know how much difference between adjacent profile segments is due to real structural variation and how much is associated with differences in acquisition and early processing. Are there descriptions of any sensitivity analysis in the various migration and attribute enhancements available? The authors describe the seismic images, interlaced with geological interpretation, sector by sector. I think the narrative would flow better if the seismic reflector patterns were described first and then interpreted. The interpretation of any seismic profile of course carries uncertainty – and this is especially true for imaging complex structures in non-sedimentary successions. The paper would benefit if the authors’ preferred interpretation strategy and expectations were laid out explicitly at the outset. The introductory preamble is useful but maybe presents a rather optimistic view of the relationship between a seismic image and deformation structures in the crystalline crust. There are two distinct parts to this. The discussion assumes that the reflectivity in the, rather transparent, upper part of the profiles (less than 4-5 s TWT) is from faults/shear zones which therefore have a very simple form. This expectation is despite the complex geology and structural geology reported from outcrop. I think the interpretation of apparently continuous inclined (and locally apparently listric) reflectors in the top 5 seconds to be faults is at least open to debate. While cartoons of idealised imbricate thrust systems show such structures, they are pretty rare in my experience in nature! Second, the authors expect the continental crust to have a long-distance layered character with geophysically distinct “upper”, “middle” and “lower” crust. Where this tri-partite structure is obscure in their images they infer “missing middle crust”. . . . Of course there is middle crust present – there’s not a void between deep crust and

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upper crust layers! So presumably they mean that the interval between say 4-8 s TWT does not match their expectations. . . . Certainly, it is interesting that the transect shows a consistently reflective seismic “lower” crust (i.e. c 5-11 s TWT) – though it may be better to say that there is a consistently near-transparent shallow crust (1-5 s TWT). Personally I’d make more of the sub-Moho reflectors – perhaps referencing other such features imaged elsewhere in the world (e.g. the Flannan “event” in BIRPS images). If the authors are correct in their interpretation that the Iberian crust has been stacked by thrusts, then long-range layering might not be expected. . . unless it over-prints the Variscan structures. . . in which case how much of the image relates to Variscan tectonics at all? The points made above indicate that I found the rolling discussions on the tectonic interpretation rather confusing. This may reflect the the difficulties in reconciling competing views amongst the extensive authorship! The Geological Setting notes are useful but quite involved, detailed and dense. The only illustration that accompanies the text is the geo-tectonic map of Iberia. As such it is very difficult to follow. How much of this do I, as a reader, need to retain to pick up the story...? For example, is the timing and delay of anatexis (line 132) really needed for the interpretation of the seismic data later? The message I get from the “Geological Setting” is that the structure of the present-day near surface is complex. . . including folds – that include deformed thrusts and thrust sheets (e.g. lines 150-157; line 187) – which is not conducive to their seismic imaging. . . For readers not familiar with region, some kind of palaeotectonic framework diagram could help to reinforcing the content. Likewise, some simple diagrams illustrating the competing models and interpretations of crustal structure would be useful – and these could then allow the seismic interpretations of the composite profile to be reframed as tests against these models.

Line 770 etc alludes to important ambiguities resulting from the interpretation of out-of-plane and migration artifacts. More could be made of this in discussion of interpretation uncertainties.

The interpretation is interwoven with basic description of seismic character. I think the

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narrative would flow better if the seismic reflector patterns were described first and then interpreted. The narrative would benefit from a simple statement of assumptions and the preferred model at the outset (see above) – as much of the discussion here takes much of this as read. For example – line 461 and on states that the variations in the thickness (in TWT) of the reflective layer (“lower crust”) imply differential thinning – extension. . . . But why? Could it not be that the reflectivity was developed heterogeneously ? Or that the thicker portions have been thickened, rather than the thinner ones thinned?

Section 3.3 Is called a description of the seismic sections. It would be better indeed if this was what it was.. In fact, the section interlaces basic description of the seismic character with geological interpretation. In my view, the narrative would flow better if these two aspects were decoupled – so that first order description (“observations”) are separated from the interpretation.

So describe reflection dips . . . Then say you infer that these track shear zone/thrust zone trajectories. Therefore where they go sub-horizontal then you deduce regional floor thrust positions.

Section 4.3 There are not many places in the world, away from Cenozoic orogens and basins, where continental crust is not underlain by a largely sub-horizontal Moho. Whether this represents gravitation flow of deep crust or simply differential isostatic rebound and concomitant erosion is debatable. Just how much upper crustal extension is there (stretching factors) from place to place? In settings like the Variscan – is the Moho a passive pre-orogenic marker – or is it a (partly magmatic or metamorphic) construct? There are interesting points in this discussions – many further references could be added. . .

Section 4.4 I found the premise here confusing. Metamorphic units are notoriously metastable – after all we get granulites and eclogites at the Earth’s surface. Only if the metamorphism was in equilibrium and therefore over-printed previous assemblages

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along modern (sub-horizontal) isotherms would the crustal seismic structure be as discussed here. But if so -the tectonic structure would (presumably) be hard to resolve – the intensities of reflectivity in the profiles could simply chart metamorphic (thermal) structure – not intensities of deformation as assumed here). . . . You allude to this (line 761-2). But if so – when is the layering established? Presumably post-tectonically (after thermal re-equilibration). . .

In the final discussion on the mid-crustal structure – description of the geophysical character is continuously intermingled with interpretation as a tectonic discontinuity. I would find it helpful if these two distinct aspects were separated. By all means set up the discussion in terms of Conrad – which is a geophysical construct. But make this distinct from its geo-tectonic interpretation.

Some detailed comments.

Personally, I find the continual use of acronyms distracting – especially short ones. It is easier for readers if you use Cantabrian Zone rather than CZ for example.

Line 57 – more complete than what? Better to say Our aim here is the present a composite seismic profile that integrates results from two new experiments (IMDEF and ALCUDIA WA) with existing data-sets (specify).

Line 60 – “Later on” makes it sound like it is another paper. “Here we continue to. . .” or some such might be clearer. . . continuing. . . We revisit interpretations of crustal extension and a possible mid-crustal discontinuity. We discuss mid-crustal reflectivity, the so-called “Conrad Discontinuity” of classical continental seismology (Conrad 1921), in the light of long-running debates as to its tectonic significance (REFS).

Line 87 – strictly the correlation does “support” the affinity – it is consistent with it . . .

Line 88 etc “Evidences” - the plural of evidence in this context is “evidence” (no “s”, like sheep).

Line 95 – “in the surface” – do you mean at outcrop?

Line 98 – what is “it”? The structure of the Iberian Massif along a N-S transect...?

Line 139 and Line 140 etc. Be consistent with the verb... – is it “cop out” or “outcropping”..

Line 183-184. Statements like this are key... mid crustal reflectivity can be explained by intrusions... But what evidence is there that they were controlled by shear zones? Why does reflectivity necessarily track deformation?

Line 229 etc. a plural of a date has no apostrophe – it’s 1990s...

Line 237 – kind of experiment (no need for plural).

Line 285-287. Please reference explicitly these primary sources for the seismic processing. Hopefully these are peer-reviewed, formal publications!

Line 305 (and many other places). Interpretation is presented as fact. So “W-dipping reflections that represent the Variscan imbrication” – is highly interpretative. First it would help if this statement is justified... How explicitly does the reflectivity match to outcrop structure?

Line 312 – Interesting – but when thin-skinned interpretations were provided by (eg) COCORP Appalachians from 1970s– they tied reflectivity to underthrust sediments that could be traced down from outcrop...

Line 448 etc. I’d avoid using the phrase “is related to” when discussing the seismic expression with respect to the surface geology. A better basic phrase is – “coincides with” – as this avoids associating description with interpreted causation...

Line 459 – Can you exclude the “cross-cutting” relationships are in-plane migration (or out of plane) artifacts...?

Line 477 “Mantle” reflectivity – what evidence is there to support the notion of crust-mantle imbrication? Could this not be intra-mantle structure?

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Line 707 – which author? Meissner??

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