

Interactive comment on “Control of 3D tectonic inheritance on fold-and-thrust belts: insights from 3D numerical models and application to the Helvetic nappe system” by Richard Spitz et al.

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General comment

All in all this manuscript addresses an interesting topic in a clear way. My comments in this review are meant to improve the manuscript.

Abstract is too long. The first three sentences is not what you found. They should be in the aims part of the introduction. The important statements are found from line 10 to 24.

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1 Introduction is OK

2 Geological overview is OK, but a few corrections needed (see specific comments).

3.1 Numerical method OK, but the mathematical part is not my field of expertise. Fig. 3 is hard to read (dark red color hinders 3D visualization, model types are too small to read) 3.2 Model configuration: description is OK. But I think that the simple geometry of a graben getting narrower linearly is not the best solution. It might well be that the passive margin is fragmented as shown by Trümpy for the Early Jurassic in eastern Switzerland with NS-striking synsedimentary faults (transformlike). Considering the en echelon pattern of the hinge lines of the Morcles and Doldenhorn nappes it seems more logical to use a fragmented basin (an offset placing the northern graben bounding fault farther South for the Doldenhorn area). Fragmented passive margins are more the rule than the exception (see papers by the Manatschal group in the Austroalpine units, the Pyrenees and the Atlantic off Portugal).

4. Results 4.1 Section on 3D Model evolution is OK, Fig. 4 is a nice summary graph, which would fit into section 5.1 4.2 Section on 2D numerical cross-sections. Cross-sections are clearly presented, but the wealth of data seems somehow “too much”. The figures could be condensed by showing two cross-sections, at $x=0$ and $x=40$ km. The intermediate states show basically the same features and do not exhibit significant changes. The text would of course need to be modified (shortened) accordingly. The full detail could be provided as supplementary material. 4.3 Nadai strain and lode's ratio is OK, but I asked myself what you wanted to extract from this information. The deviation from plane strain has been a problem in structural geology that never has been satisfactorily been resolved. Your 3D modeling could give us some clues. But even in the discussion and conclusion you do not take advantage of the data the model provides.

5 Discussion 5.1 Impact of lateral geometry variation is OK. Fig. 4 would be well (better) placed in this section! 5.2 Comparison with the Helvetic nappes is OK, with

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a few corrections that need to be included (see specific comments). 5.3 Comparing geological with modeled cross-sections, Morcles nappe. This section has important flaws (see specific comments) such that I tend to suggest deleting it.

6 Conclusions are a bit lengthy. They contain statements that belong to the abstract. True conclusions (what was learned from the research) formulated to the point. Some of the language is a bit cumbersome (see specific comments)

Specific comments

55 You mention analogue models but do not discuss them at all later. If you wish to make reference to analogue models you need to add a few explanations with references.

123 It is important to note here that it is the Early Jurassic basin that plays the major role in the development of the internal structure of the nappe. This basin is restricted to the area west of the Aar massif. In eastern Switzerland the Early Jurassic basin is restricted to the area south of the Aar massif. "North Helvetic basin" is misleading as term (it is also used in conjunction with flysch basins).

134 see 123

136 which carbonates are you referring to by saying "in between"? The carbonates are of Late Jurassic and Cretaceous age and rest on the marly-shaly Early and Middle Jurassic sediments.

137 I disagree with these differences: for Morcles shearing at its base is really prominent as well and the internal folds of the Doldenhorn are isoclinal in part, and the length of the overturned limbs are comparable.

150 The Rawil depression is not a "topographic" feature (Wildhorn and Wildstrubel are among the higher peaks). It is a structural depression.

152 The Early Jurassic basin is not proven to be continuous. As a matter of fact the

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hinge lines of Doldenhorn and Morcles are clearly not lined up and can therefore not be correlated. These hinge lines are most likely controlled by the basin architecture, which is a primary target for this study. By saying that the basin is continuous you are making an assumption that you want to investigate by your study. If the hinge lines of Morcles and Doldenhorn reflect the orientation of the northern basin border then this border must have a jog. Some people (e.g. Burkhard) explained this jog as a NS-striking strike-slip fault. But in reality we do not have any data on this. The seismic data of NRP20 are inconclusive on this.

154 The statement "absence of significant nappes in the Infrahelvetic complex" does not correspond to reality: there are three major nappes (Kaminspitz, Calanda and Tschep), all of which have significant displacements. But what they lack are recumbent folds, a fact that reflects the absence of an Early Jurassic basin and the Middle Jurassic sediments being very thin in comparison to the Late Jurassic and Cretaceous carbonate sequences.

155 The Doldenhorn nappe is much much closer in style to the Morcles nappe; it displays long inverted limbs which are absent in the Glarus nappe complex in eastern Switzerland.

160-162 This interpretation is contested sharply by Pfiffner et al. (2011).

509 The Chamonix-zone does not show a synclinal structure in nature. The Mesozoic sediments show a consistent younging from the Mont Blanc massif to the NW. The youngest sediments then but against the Aiguilles Rouges massif's basement. This is clearly visible from the structural maps 1:100'000 that you cite earlier on (Pfiffner et al. 2010).

498 This statement about the Helvetic nappes needs a reference.

512/13 Fig 14 The intention of this figure is much appreciated. I have some worries though if strain ellipses determined from pressure shadows are directly compared to

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strain determined from deformed oolites. And what are the contributions to the figure by Bastida, Dietrich & Casey, Casey & Dietrich? Strains or cross-sectional geometry? Or are all the strain data from Ramsay & Huber? And I miss the effect of the Permo-carboniferous graben in the Aiguilles Rouges massif (it is partially inverted and folds the Morcles thrust above).

578-605 It is no surprise that the three cross-sections chosen from along strike give different results. Cross-section shown in Fig. 15a is from the Rawil depression where the Morcles-nappe is deeply buried in the subsurface and thus drawn by projection only. The top basement beneath is constrained by seismic data of NRP20 and thus explains somewhat the reduced thickness of the nappe. However, I never put a name to the basement uplifts because of the uncertainty involved and urge the authors to delete them. One could equally well put the names of the Gastern and Aar massif in their place. The cross-section is more reliable for the Wildhorn nappe since this nappe outcrops along the trace of the cross section. The cross section shown in Fig. 15c shows a completely different nappe – and I doubt very much that it should be called Morcles nappe. In fact the Morcles nappe in the type locality “Dent de Morcles” displays hinge lines of internal folds that climb westwards over the Aiguilles Rouges massif, crossing its crest line and then plunge towards the SW beneath the Chablais and the Chaînes Subalpines thrust sheet. The structures shown in Fig. 15c are merely in the same structural position relative to the Chaînes Subalpines thrust sheet. The uncertainty emanating from the construction of (balanced) cross-sections could be extracted from the numerous cross-sections drawn along the trace of the cross-section shown in Fig. 15b. One of the main reason for divergent solutions is the observation that the lower limb is more horizontal whereas the upper limb plunges with 30° to the NE (see discussion in Pfiffner 1993, a reference referred to in the manuscript). There aren't many cross-sections constructed along curved hinge lines as is necessary in this situation. The one shown in Pfiffner (1993) is based on the construction of Langenberg et al. (1987) who did use curved hinge lines. The major effect of the differing plunges is the thickness of the Morcles nappe. Curved hinge lines yield a thickness of ca. 5 km, the

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cross-section by Escher et al. (1993) used in Fig. 15B suggests 7 km.

609-613 Does not present a conclusion. For me one important conclusion is the next following sentence (Nappe detachment, transport . . .)

618-619 The importance of fieldwork in such a scenario is common sense.

623 This is the place that screams for a statement on the nature of the strain in and out of the cross-sectional planes.

628-638 These are findings that should go into the abstract.

Technical corrections

18 French-Swiss Alps is not a common denomination. I suppose you wish to include the Haute Savoie part of France. I suggest “Central Alps of France and Switzerland”

74, 108 see 18

76-77 “laterally” instead of “along the lateral direction”?

111 I suggest “Glarus nappe complex of eastern Switzerland”

148 Diablerets

326 2D numerical cross sections: why specify “numerical” here? All is numerical. And wouldn't “thrust sheet” be a better term than “thrust nappe”, particularly as it is opposed to “fold nappe”?

496-497 suggestion: The resulting model nappe stack shows laterally major structural differences.

515 It would be better to formulate what is observed, and not what is not observed (contact to basement)

548 report (not reports)

549 frontal part

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551 Doldenhorn and Glarus nappes (or Doldenhorn nappe and Glarus nappe complex)

554 suggest

563 start a new paragraph with “In terms of. . .

624 modeled by a stress cut-off at 40 MPa (instead of “due to”)

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