



ELSEVIER

Journal of Structural Geology 25 (2003) 2161–2163

**JOURNAL OF  
STRUCTURAL  
GEOLOGY**

[www.elsevier.com/locate/jsg](http://www.elsevier.com/locate/jsg)

## The Bude Formation, SW England: a reply to the comments by J. Treagus<sup>☆</sup>

Geoffrey E. Lloyd\*, Nicholas Chinnery

*School of Earth Sciences, The University, Leeds LS2 9JT, UK*

Received 19 December 2002; received in revised form 11 February 2003; accepted 26 February 2003

We thank Treagus (2003) for his discussion of our paper (Lloyd and Chinnery, 2002) concerning a re-interpretation of the Upper Carboniferous Bude Formation of SW England as a three-dimensional intra-formational imbricate stack that evolved during late Variscan deformation. His discussion allows us to correct a potential misunderstanding regarding the orientation of a profile section presented in our paper (i.e. Lloyd and Chinnery, 2002, Fig. 6). It provides also a further opportunity for us to emphasise the crucial differences between our model and previous models (e.g. Ramsay, 1974; Freshney et al., 1979; Sanderson, 1979) for the geological evolution of this classic section.

The first comment made by Treagus (2003) concerns our Fig. 6 (Lloyd and Chinnery, 2002) and in particular the viewpoint of the cliff profile section. The positioning of the text on this figure has clearly led Treagus to adopt a *view-to-the-west* rather than our intended *view-to-the-east* perspective. Unfortunately, as recognised by Treagus, a westerly viewpoint automatically inverts the cliff profile section from our intended orientation. This was an unfortunate error of compilation on our part, for which we apologise. Fig. 1 therefore is a reduced and simplified version of our original map and cross-section (i.e. Lloyd and Chinnery, 2002, Fig. 6) with the text written in an appropriate orientation and we take this opportunity to emphasise that the cliff profile section should be viewed *towards the east*. However, in our defence, we must state that cliff profile sections on north–south coastlines with the sea to the west usually can only be viewed by looking towards the east.

The second comment made by Treagus (2003) concerns a comparison between our structural cross-section and that presented in Freshney et al. (1979). Treagus (2003, Fig. 1) has chosen to base his discussion on a comparison between

the large scale, and therefore necessarily simplified, cross-section presented by Freshney et al. (1979, Fig. 2) and our more detailed cross-section (e.g. Fig. 1; see also Lloyd and Chinnery, 2002, Fig. 6). To facilitate his comparison, Treagus (2003, Fig. 1a) chose to re-draw our cross-section (*in our original and intended orientation*) to the same scale as that of Freshney et al. (1979). In fact, we had included in our original manuscript submission a version of our cross-section drawn to the same scale as Fig. 2 of Freshney et al. (1979). Unfortunately, space limitations meant that it could not be included in the final paper. Here, we take the opportunity to reproduce this cross-section (Fig. 2).

Treagus (2003, Fig. 1) concluded from his comparison of the two cross-sections drawn to the same scale that the principal difference between them is in the sheet dip of the Bude Formation in the central section (i.e. between Northings 083 and 103). In the Freshney et al. (1979) section, the sheet dip is shallow towards the north, whilst in the Lloyd and Chinnery (2002) section it is approximately horizontal. We suggest that this difference, as drawn, is *insignificant*. Indeed, the sheet dip of the Bude Formation between Northings 090 and 100 is essentially horizontal in both sections. However, we cannot accept the representation of our detailed cross-section (Lloyd and Chinnery, 2002, Fig. 6) as drawn by Treagus (2003, Fig. 1a). In his interpretation, Treagus has included only a single *continuous* thrust structure through the central section. Although the sheet dip of this thrust appears to be horizontal, most of it occurs below wavecut platform level. In our section drawn to the same scale (Fig. 2) we have included also the ‘roof thrust’ to this ‘floor thrust’. Whilst we agree that the ‘floor thrust’ has a horizontal sheet dip, the ‘roof thrust’, which occurs predominantly in the cliff profile section, clearly has a sheet dip towards the north, similar to that shown in the Freshney et al. (1979) section (see Treagus, 2003, Fig. 1b). The two thrusts actually form a wedge, termed the ‘Sandy Mouth Thrust Sheet’ (Lloyd and Chinnery, 2002, Fig. 12), that both dips and tapers towards the north. Thus, the

\* Corresponding author. Tel.: +44-113-233-5222; fax: +44-113-233-5259.

E-mail address: [g.lloyd@earth.leeds.ac.uk](mailto:g.lloyd@earth.leeds.ac.uk) (G.E. Lloyd).

<sup>☆</sup>DOI of comment article: 10.1016/S0191-8141(03)00047-6; PII of original article: S0191-8141(01)00130-4

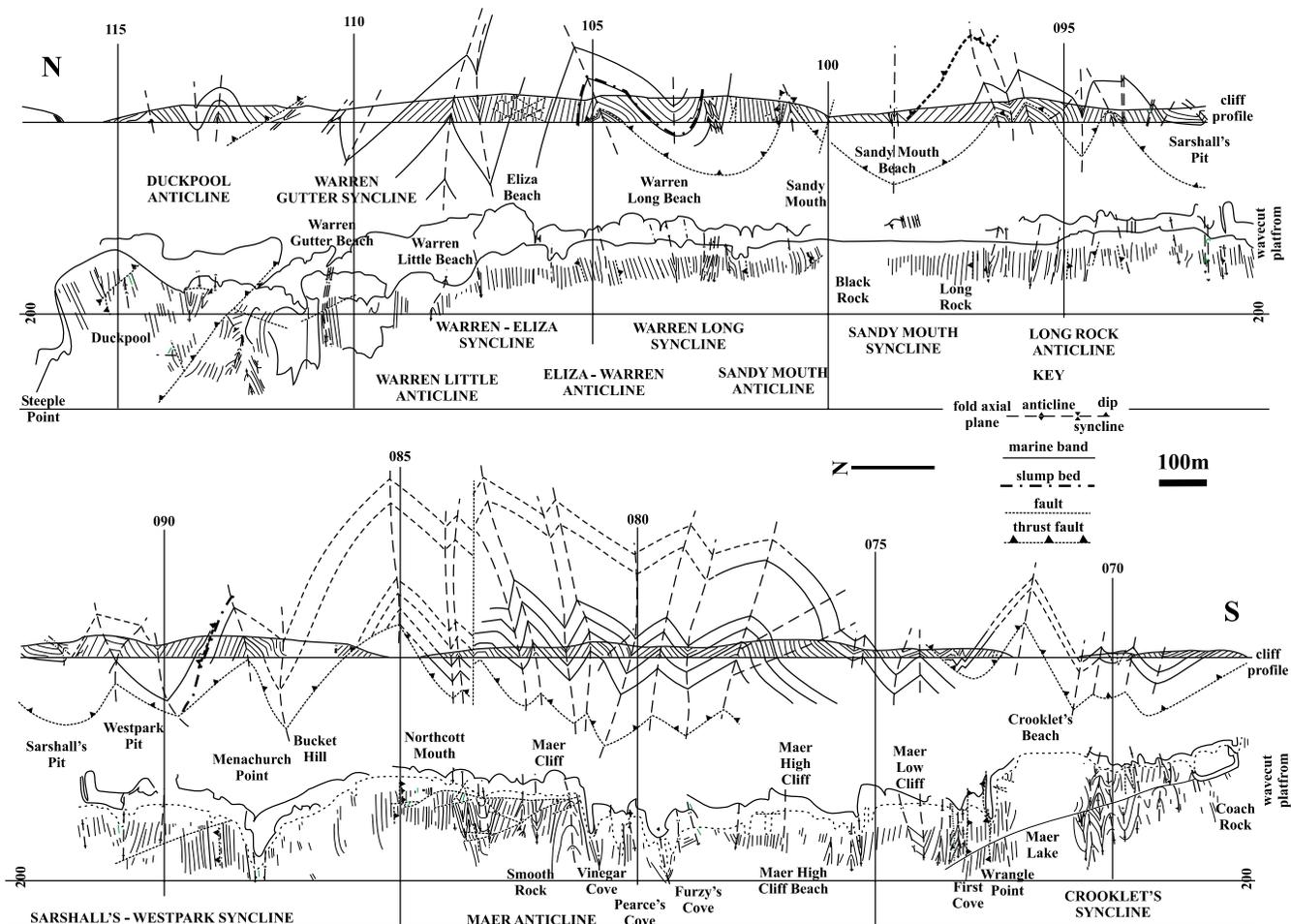


Fig. 1. A reduced and simplified version of the wave cut platform map and cliff profile section presented in Lloyd and Chinnery (2002, Fig. 6), in which the text has been redrafted to emphasise the *view-to-the-east* perspective intended in the original diagram.

present day structural cross-sections as drawn by ourselves (e.g. Figs. 1 and 2) and Freshney et al. (1979, Fig. 2) are broadly similar.

It is not surprising that the two cross-sections are similar as the present day configuration of the Bude Formation is

due mainly to the effects of essentially upright chevron folding and normal faulting, which are common to both interpretations (Freshney et al., 1979; Lloyd and Chinnery, 2002). We doubt therefore whether it will be 'instructive to make a comparison of the two cross-sections' simply on the

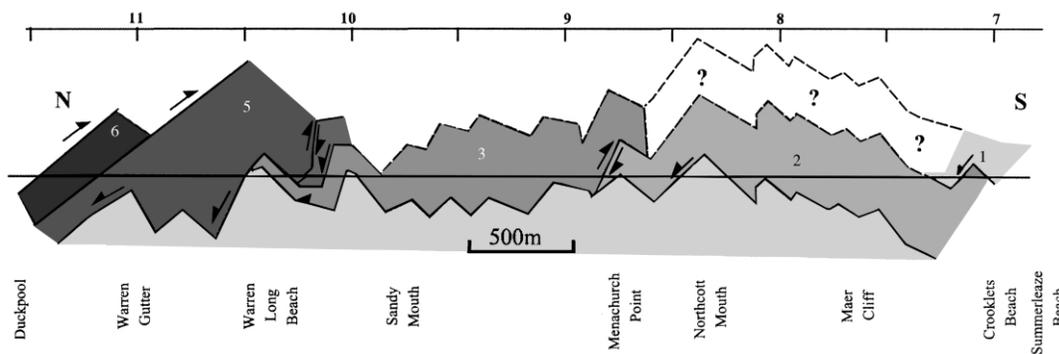


Fig. 2. Simplified representation of the detailed cross-section presented in Lloyd and Chinnery (2002, Fig. 6) drawn to the same scale as Freshney et al. (1979, Fig. 2) and including the intra-formational thrust structures that define a sequence of thrust sheets (numbered 1–6) and both thicken and repeat the Bude Formation (compare with Fig. 1a of Treagus (2003)). Note how the roof thrust to sheet 3 dips towards the north, similar to the sheet dip of the Bude Formation suggested by Freshney et al. (1979).

basis of sheet dip. However, the principal aim of our paper was to describe the presence and significance of the hitherto unrecognised intra-formational thrust structures present within the Bude Formation. Such thrust structures typically pre-date the chevron folding and normal folding. Unfortunately, the cross-section offered by Treagus (2003, Fig. 1a) as an accurate representation of our detailed cross-section (Lloyd and Chinnery 2002, Fig. 6; see also Figs. 1 and 2) simply fails to include these crucial thrust structures. Thus, the truly 'instructive comparison' between the two cross-sections proposed is whether the conventional *continuous stratigraphy* interpretation of Freshney et al. (1979, Fig. 2) (see also Ramsay (1974) and Sanderson (1979)) or our recent *intra-formational thrust pile* interpretation (Lloyd and Chinnery, 2002, Figs. 6 and 12) is correct. We believe that our interpretation, based on detailed structural mapping and sedimentary sequence logging, provides a viable explanation for many of the structural and stratigraphic problems that were in fact recognised and described

but not explained by Freshney and his co-workers in their seminal contributions (e.g. Freshney et al., 1979).

## References

- Freshney, E.C., Edmonds, E.A., Taylor, R.T., Williams, B.J., 1979. Geology of the country around Bude and Bradworthy. Memoirs of the Geological Survey of Great Britain, Sheets 307 and 308.
- Lloyd, G.E., Chinnery, N., 2002. The Bude Formation, SW England—a three dimensional, intra-formational imbricate stack? *Journal of Structural Geology* 24, 1259–1280.
- Ramsay, J.G., 1974. Development of chevron folds. *Geological Society of America Bulletin* 85, 1741–1754.
- Sanderson, D.J., 1979. The transition from upright to recumbent folding in the Variscan fold belt of Southwest England: a model based on the kinematics of simple shear. *Journal of Structural Geology* 1, 171–180.
- Treagus, J., 2003. The Bude Formation, SW England: discussion. *Journal of Structural Geology* this issue (doi:10.1016/S0191-8141(03)00047-6).