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Autor: Ramsay, John G.

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Fold and fault geometry in the Western Helvetic nappes of Switzerland and France

by *John G. Ramsay*[1]

Abstract

Compilation of exisiting published maps together with structural remapping of the Western Helvetic nappes and northern sector of the Chaînes Subalpines show that folds characterise the internal structural pattern of the nappes. The fold geometry is accounted for most convincingly by layer parallel shortening and buckling instabilities developed in an alternating series of competent and incompetent strata and not by structural adjustments of the hanging walls of overthrust sheets to the irregularities in the morphology of the underlying thrust surfaces (fault bend folding). Individual major folds have regionally constant axial orientations and persist for distances which may exceed 80 km along their axes. The fold orientations together with the orientations and values of the rock strain induced by the internal nappe deformation support the view of an initial development by northward overthrusting, followed by later overthrust movements towards the northwest and west.

Keywords: Helvetic nappes, thrust and fold geometry.

Introduction

The Ultrahelvetic and Helvetic nappes of West Switzerland and eastern France are comprised of a number of thrust sheets of Mesozoic and Tertiary sediments. The emplacement history and successive activation of individual nappes can be deduced from their geometric relationships. The Ultrahelvetic units were first overthrust on to a relatively undeformed foreland region (later to be the site of the Helvetic nappes). This foreland then became tectonically active as a result of continued subduction of the European continental basement and overlying sedimentary cover under the North Italian (Apulian) plate. This continued subduction led to basement shortening (by ductile shear zone formation) together with overthrusting of the sedimentary cover to form the present Helvetic nappes. The Ultrahelvetic nappes were resheared and refolded by the activation of the Helvetic thrust sheets; COLLET (1927). The geometry of the Helvetic units suggests that the Wildhorn and Diablerets sheets probably together with the folding of the upper limb of the Morcles nappe were the first to be activated and that the lower limb of the Morcles fold together with the deformation of the cover of the parautochthonous Aiguilles Rouges and Aar massifs were the sites of the latest major deformation; COLLET (1927), DIETRICH and DURNEY (1986), DIETRICH (this volume). However this picture is probably not quite so simple in detail because the folds of the upper limb of the Morcles nappe are slightly truncated by the basal thrust of the Diablerets nappe, and in the Swiss-French frontier region the folds in the frontal part of the Morcles nappe are partially truncated by the basal shear planes of the Ultrahelvetic and Pre-Alpine nappes. Probably as the nappe packets overlying the Morcles nappe were incrementally sliding forward, at least locally, during the main development of the Morcles nappe.

New work in the region

The region between Kandertal and Lac d'Annecy has been remapped at a scale of 1:25,000 and compiled at 1:100,000 as part of a research projects funded by the Swiss Nationalfonds (2.214-0.86 and 4.963-0.85.20). Special attention has been given to mapping the axial surfaces of individual folds, and establishing the orientations of all the major fold hinge lines. Because of

[1] Geologisches Institut, ETH-Zentrum, CH 8092 Zürich

strong topographic relief and the general low inclination of the fold axial surfaces the zones of the fold limbs, located between anticlinal-synclinal fold pairs, show complex map patterns; RAMSAY (1989). In contrast the orientations of the fold hinges located at specific lithological levels are remarkably constant (WSW-ENE) from Kandertal to the Arve valley and only begin to curve into the arc of the Chaînes Subalpines southwest of the Arve valley. Another special feature of the folds of the Helvetic nappes is the remarkable lateral persistance of individual folds and fold limbs. In the Wildhorn nappe individual folds can be traced across the Wildstrubel depression for distances exceeding 40 km, while the two major anticlines which form the core of the Morcles fold nappe can be traced from the type locality of the nappe, situated in the mountain group of the Dent de Morcles and Grand Muveran, towards the south west into the folds of the Chaînes Subalpines for more than 80 km along their hinges; RAMSAY (1989).

Although some structural features of the Helvetic nappes accord with the "ramp-flat" model of RICH (1934) and BOYER & ELLIOTT (1982), the geometry of most of the observed folds indicates an origin by layer shortening and buckling mechanisms RAMSAY, CASEY & KLIGFIELD (1983) and not directly by passive fault bend folding; SUPPE (1983). The frontal cascade-like folds seen in the Wildhorn and Diablerets nappes appear to be best explained by intense layer parallel shortening produced by simple shear imposed on competent and incompetent strata inclined to the nappe boundaries. The concentration of this layer shortening seems to coincide with the hanging wall ramp-like structure where the underlying thrusts cut relatively steeply upwards through middle Cretaceous strata. In contrast, the layer shortening and folding intensity above hanging wall flat sections is much less (eg. in the main sector of the Diablerets nappe), a feature attributed to the fact that the shearing plane parallel to the nappe contacts and layering is a surface no finite longitudinal strain.

In the lower limb of the Morcles fold nappe the strains arising by simple shear have led to extremely high deformation states in all the strata [$(1+e_1)$: $(1+e_3)$ up to 100:1]; RAMSAY (1981). When the fold profiles are viewed from the WSW towards the ENE they are seen to have Z-shaped forms as expected on the inverted limb of the overall anticlinal form of the nappe, and great reductions of layer thickness. The stratigraphic succession, even though inverted, is quite coherent showing an overall reduction by a factor of about 0.1 to the thickness of the pretectonic succession. These geometric variations are consistent with an imposed ductile shear strain in the inverted limb with shear values (γ) of about 10.

The earliest shear motions in the Helvetic nappes, deduced from the finite and incremental stretch directions, were in a south to north overthrust sense. In contrast, the strains in the lower limb of the Morcles fold (DIETRICH and DURNEY, 1986) and in the internal parts of the Chaînes Subalpines show a change of overthrust sense to north westerly and westerly interpreted as a regionally significant change of direction of the relative plate movements in the Alps as a whole; DIETRICH and DURNEY (1986), DIETRICH (this volume), RAMSAY (1989).

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