The origin of the Marwies Fold in the Säntis mountains

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By PH. H. KUENEN (Leiden).

With 5 figures.

The Säntis forms an exceedingly fine example of a small, but intensely folded range and the monograph by ALB. HEIM, with collaboration of his son ARN. HEIM, MARIE JEROSCH and E. BLUMER, is a classical contribution to Swiss geology[1]). The most remarkable feature of the range is the complicated fold of the Marwies. In the following article no attempt is made to alter, or to interprete otherwise the field evidence collected by HEIM, but a new "ontological" explanation of this peculiar tectonic feature is given, that leaves the sections and map unchanged.

The Säntis is the foremost fringe of the Säntis-overthrust-sheet (Deckblatt) and is formed by a series of steep, parallel folds, cut by a number of transverse faults, and thrust over and up against the Molasse foreland, showing what HEIM characterises as "Brandungsfront" (Surf-edge). The Marwies is one of the folds lying in the centre of the range, forming a unique example of a refolded anticline. The Marwies anticline curls over into the adjoining Meglisalp syncline in the manner of brakers on a flat beach. Fig. 1 is redrawn from one of HEIM's sections, with a few insignificant alterations.

An attempt will here be made to explain the present position of the downwarped crest C. Although HEIM nowhere definitely states his opinion as to the development of the exceptional features, evidently refraining from theoretical speculations, it seems from various statements that he believes this overfolding to be the last result of the tangential stress, and the crest to have sunk downwards as the anticline became too high. The thrust from behind pressed it forward into the soft Eocene and Seewerkalk beds. We quote the following sentences: p. 94, "Offenbar sind also hier zwei normale Schichtenreihen in verkehrte Lage überkippt, der verkehrte Mittel-

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[1]) Das Säntisgebirge. Beiträge Geol. Karte d. Schweiz. Neue Folge XVI (1905).

schenkel aber ist nochmals über die Senkrechte hinausgedreht, hat dadurch wieder normale Schichtenfolge erhalten und muss so doppelt umgekehrt und dadurch wohl auch um so mehr reduziert worden sein". p. 44: ".... dass nördlich überliegende Gewölbe mit ihrem Gewölbescheitel tiefer sinken und durch Fortgehen des Horizontalschubes völlig eingewickelt werden, so dass die "Falte der Falte" entsteht". In his "Geologie der Schweiz" (1921) he says on page 363: "... die Stirn der Falte sich derart nördlich überschlagen hat ...".

For the following reasons this view seems improbable. A, the resistance offered to the curling down crest C would have been very

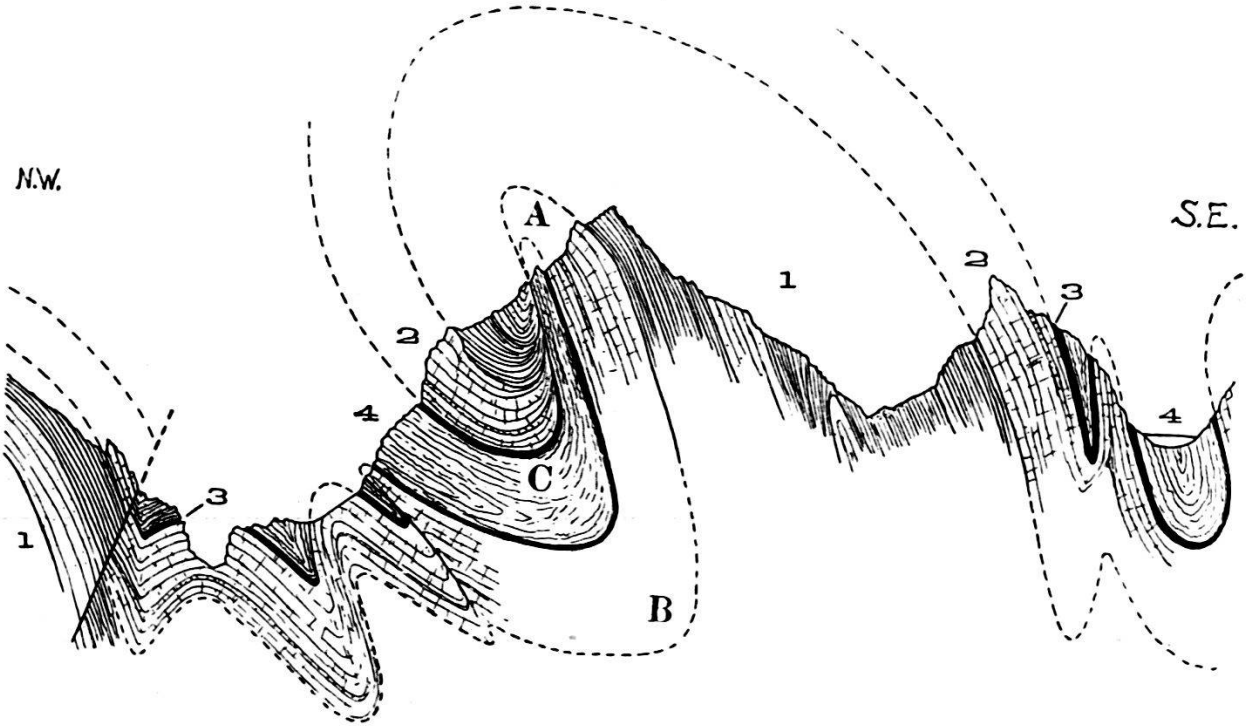

Fig. 1. Section across the Marwies after HEIM (Tafel III, Pr. 18). Scale 1 : 25,000.
1 = Valangien and Neocomien; 2 = Schrattenkalk; 3 = Gault; 4 = Seewerkalk.

large; B, the only force directed downwards was the weight of the crest itself; C, absence of erosion in the crest at C, fig. 1.

A. *The great resistance.* In fig. 2 the order of events, when assuming the above mentioned theory, is represented. Two earlier stages are indicated by dotted and drawn-out lines. It will be seen:

a) that the strata had to be greatly distorted;

b) that a considerable amount of material (Seewerkalk and Flysch) had to be pressed away horizontally, at right angles to the downward movement of the crest, before the stage of fig. 1 was finally reached. Though plastic compared to the Schrattenkalk these layers would require an enormous pressure to be

squeezed away by a force at right angles to the direction of escape, like mud from under the foot;

c) the drawing out of the layers between A and C (fig. 1) proves that the crest in pressing down had to overcome a considerable lateral pressure. In tectonics drawing out can only result from a spreading movement with pressure at right angles to its direction, otherwise fracturing occurs. Therefore there must have been lateral pressure against the crest of the anticline to ensure the reduction without fracturing of the drawn-out portion. It is of significance, moreover, that slickensides occur between the Valangien of the Gloggern and the Schrattenkalk of the Marwies, a fact pointed out by SCHARDT (Eclogae VIII, 1903, p. 403).

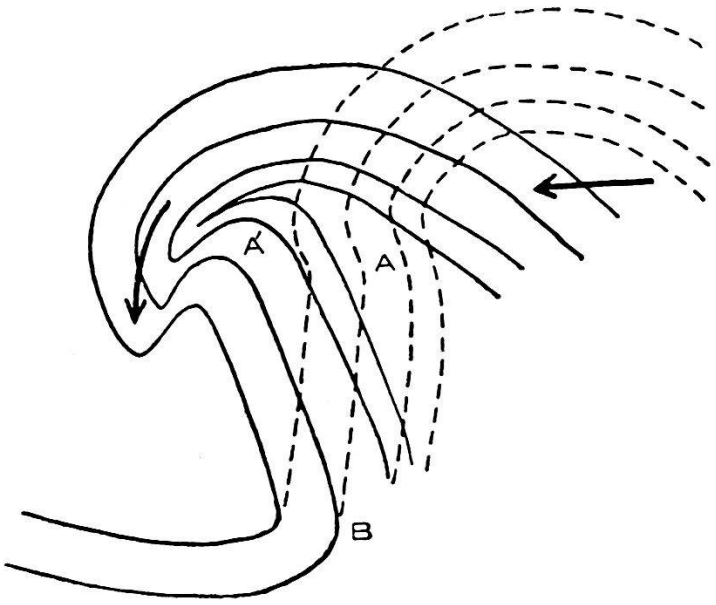

Fig. 2. Two stages in the production of the Marwies fold, the first stage dotted (interpretation of HEIM's view).

B. *The only vertical force was the weight of the anticline.* The force pressing the Säntis forward over the sub-soil was exerted in a horizontal plane, certainly not much higher than the present position of point C, fig. 1. A component in a vertical plane to press the crest into the adjoining syncline could either have been given by a resistance or by some additional force, not acting in the horizontal plane. The weight of the anticline is the only additional force in this sense.

That there was also no resistance, resulting in a vertical component being given to the horizontal stress, is almost certain. Such a resistance would have to be a great overlying mass. In the Säntis no signs of a former overlying mass (Ostalpine Decken) are present. Such a regular group of anticlines as presented by the Säntis moun-

tains, that are on the other hand of so varying a height, could not have been thrust up under a heavy covering. (See ARN. HEIM on p. 458.)

MARIE JEROSCH pointed out, moreover, that erosion had cut down deep into the anticlines long before the final stages of the folding (p. 223), which forms additional proof of the absence of an overlying mass towards the end of the folding.

C. Absence of erosion at point C, fig. 1. As stated above, it was proved that erosion had already attacked the anticlines and even worked into the synclines long before the thrust had ceased to act. If C was indeed part of the crest of the anticline sinking down at the last stages of the folding, why was it not attacked by erosion?

If the order of events is slightly changed, these difficulties are no longer present. We have but to suppose a small overthrust to

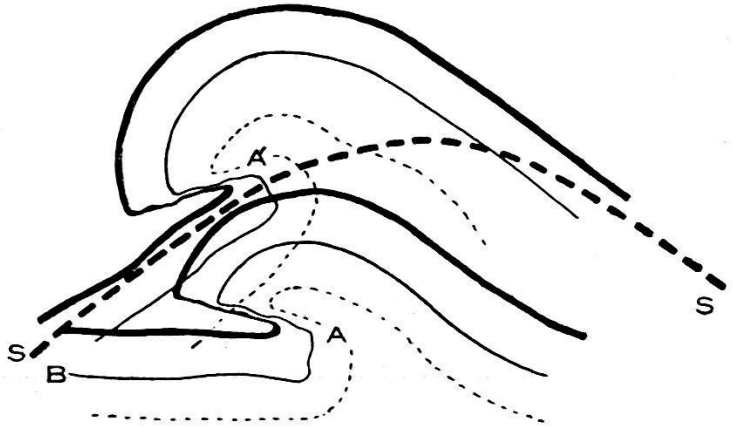

Fig. 3. Two early stages in the formation of the Marwies fold. A moves to A' as the broad anticline S–S is domed up.

have been formed at an early stage (fig. 3, bottom part) and that this complication was afterwards lifted up on the shoulders of a much broader anticline (S–S, fig. 3, top part). While erosion started in on the anticline, the updoming continued. In fig. 4 the line H represents the present erosion surface, then still buried. Finally the position of fig. 1 was reached, the erosion afterwards attaining the line H of fig. 4.

The strong distortion was thus achieved, together with the pressing aside of most of the Seewerkalk and Flysch, directly by the tangential stress. The drawing out of the part A–C, fig. 1, happened likewise in the normal manner, the weight of the upper limb supplying the pressure necessary for this thinning out. All that was now needed was the pressing away of a small amount of Seewerkalk. Besides the weight of the anticline the whole strength of the thick mass helped to squeeze the more plastic layers away. In the

first explanation the crest had still to be moved down the reduced wing at this stage of the happenings, whereas in the explanation here advocated all that was needed was that the whole mass was sufficiently strong and heavy to resist being pushed back up this plane. The slight tucking away of the crest C, fig. 1, under the anticline is now easily understood.

The section of the Oehrli, fig. 5, also redrawn from HEIM, may be looked upon in the same manner: there, too, an old overthrust has been lifted on a new anticline, but has not been turned over so far as in the case of the Marwies.

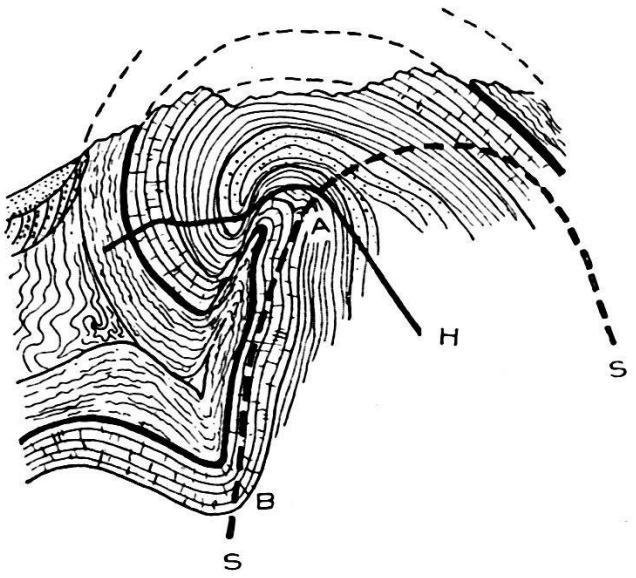

Fig. 4. Pen-ultimate stage in the formation of the Marwies; the line S–S of fig. 3 has been further curved; erosion has started to attack the crest. H is the present erosion surface, not yet in its ultimate position.

It might be urged that an overthrust would not suddenly cease to act and make place for a folding movement. But this need not be looked upon as unlikely, for HEIM and BLUMER show that the Säntis overthrust was forced over an already uneven surface of the Molasse (p. 607, 651). Under these circumstances irregularities in the substratum might easily prohibit the further development of a small overthrust in so comparatively thin a complex as the Säntis, and superimpose a new feature.

It is moreover a wellknown fact that a marked overthrust can become dormant in a mountain system and I need but remind the reader of the sections along the Weissenstein tunnel in the Swiss Jura.

Still another explanation of the Marwies fold was given by SCHARDT (Eclogae VIII, p. 403). According to SCHARDT the Mar-

wies was formed as a large, strongly inclined fold and was afterwards traversed by a secondary fold, acting as if the upper and lower limbs of the original fold were the succeeding layers of an, as yet unfolded, series. The principle objection HEIM has to this view is that it involves a more complicated reconstruction of the original shape before erosion produced the present state of affairs. It may further be pointed out that all folds in the Säntis that are asymmetrical show a considerable reduction of the northern limb. In SCHARDT's reconstruction the Marwies in the penultimate stage heeled

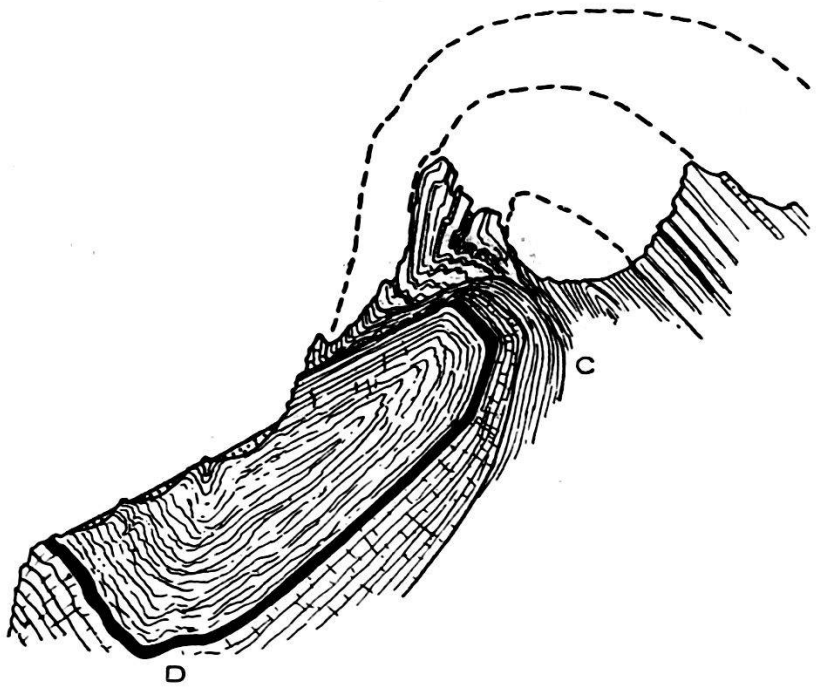

Fig. 5. Section through the Oehrli in the Säntis, after HEIM (Tafel VIII, fig. 4). Scale 1 : 10,000.

over to the north further than any of the other Säntis folds. Nevertheless the lower limb was not reduced. The great thickness of the Schrattenkalk of the Gloggern (to the left of C, fig. 1), thus forms additional strong evidence against SCHARDT's suggestion.

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