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Pull-apart stepover structures in an asphalted road surface—a geological curiosity

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Abstract

An unusual and perhaps unique example of strike-slip displacement and pull-apart stepover structures is described from a relatively newly asphalted road surface in Central Norway. The structures, which include pull-apart 'basins', show a remarkable similarity to those developed both in natural strike-slip fault systems and in physical analogue models. A surface of décollement is believed to have developed at the interface between the new asphalt layer and the old, bitumen-emulsified, planed metalled surface, perhaps aided by the presence of excess rainwater. Gravitationally induced slippage of the asphalt on this 1 in 15 gradient hill-road actually occurred several months after the asphalt had been laid. © 2000 Elsevier Science Ltd. All rights reserved.

1. Introduction

The development of pull-apart basins at releasing bends, stepover structures or extensional-splay terminations in strike-slip fault systems has been recognised in many parts of the world (e.g. Burchfiel and Stewart, 1966; Crowell, 1974; Rodgers, 1980; Aydin and Nur, 1982, 1985; Mann et al., 1983; Christie-Blick and Biddle, 1985; Guirard and Seguret, 1985); and a review of strike-slip basins has been presented recently by Nilsen and Sylvester (1999a,b). In the three decades that have elapsed since Burchfiel and Stewart (1966) first described and defined these features, physical analogue modelling has been applied widely in seeking to determine the progressive evolution of such strike-slip related, extensional domains (Emmons, 1969; Hempton and Neher, 1986; Tron and Brun, 1991; Schreurs, 1994; McClay and Dooley, 1995; Dooley and McClay 1997; Rahe et al., 1998). Mathematical and computer models (Rodgers, 1980; Segall and Pollard, 1980), including the finite-element method (Liu Xiaohan, 1983; in Guirard and Seguret, 1985), have aimed at calculating the stress configuration in and adjacent to releasing oversteps. Such experimental and theoretical models, with their information on stress–strain patterns and developing fault geometries, have proved invaluable from the point of view of integrating and interpreting field data into schemes of pull-apart basin evolution.

Given the volume of analogue data now available on the spatial arrangement of the diverse structures which can develop along linear or curvilinear strike-slip fault zones, both in map-view and in subsurface morphology, typical geometries and basins such as these can be expected to be found in a variety of scales and environments. This brief contribution serves to present an unusual example of strike-slip displacement and stepover extensional faults developed in the thin, top layer of a newly asphalted road surface, on a minor road in Central Norway. Although no more than a structural curiosity, the 'fault' patterns that developed in the road surface do show a remarkable similarity to those along strike-slip, principal deformation zones and in pull-apart stepovers.

2. Road-surface deformation pattern: geometry and kinematics

The road in question is a narrow, minor road

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branching off the main N–S, E6 highway in the valley of the river Sokna at Snøan, 10 km south of Støren (or ca. 60 km south of Trondheim) in Central Norway. Climbing the valley slopes to the mountain plateau to the east, the road has a gradient of ca. 1 in 15, perhaps locally as much as 1 in 12. During the course of a geological investigation in the area in the autumn of 1996, deformation structures were observed in what appeared to be a comparatively recently asphalted surface along this 5.5-m-wide road (Fig. 1). The deformation evidently arose during the gradual downhill slippage, or creep, of a 1.7-m-wide section of the asphalt layer, i.e. approximately one third of the road width, which had become detached along an initial rupture (concave downhill) at some unknown time after the asphalt had been laid. This had the effect of producing a natural left-lateral shear couple and dislocation along the longitudinal line between the creeping asphalt and the 'fixed' asphalt layer (Figs. 1 and 2); and simultaneously, a series of small 'faults' developed at 23–26° to the main sinistral shear structure. In three cases, small rhombohedral, transtensional areas reminiscent of pull-apart or fault-bend 'basins' had been developed (Figs. 3–5), but at the time of observation these were less than perfect in view of the wear and tear of traffic. Nevertheless, the fault patterns represented along the main line of sinistral shear are remarkably similar to those documented in many of the natural and experimental examples cited above.

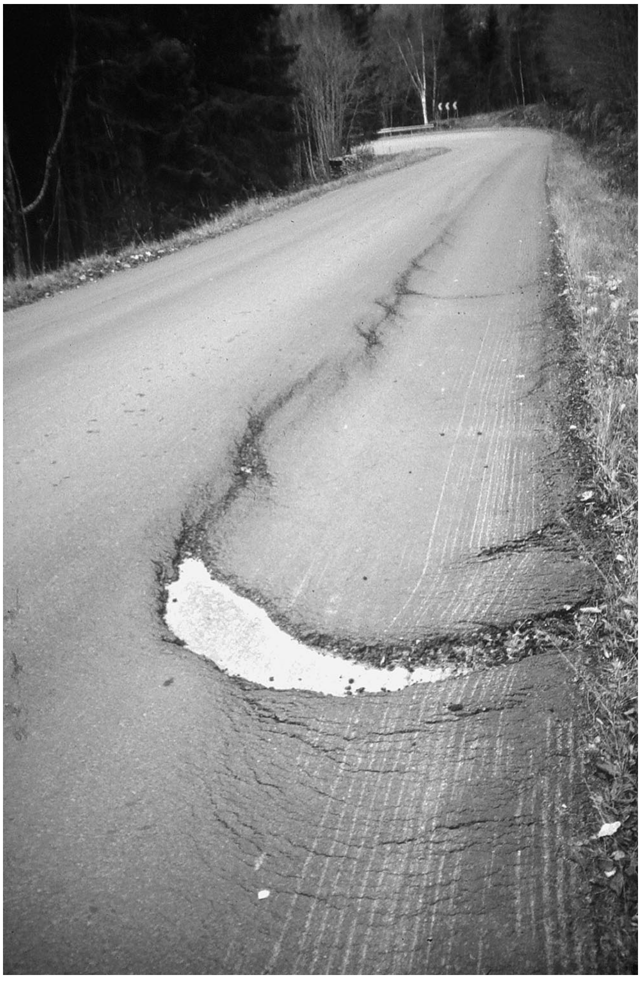

Fig. 1. The asphalted road ca. 500 m east of the E6 junction at Snøan, looking downhill towards the northwest, showing the structures that had developed arising from sinistral strike-slip movement caused by gravitationally induced creep of the 'right-hand' strip of asphalt below the prominent concave-down, rupture scar. The maximum downhill displacement of asphalt at the rupture scar is ca. 35 cm. The white stripes are scratch marks made by a snowplough.

In addition to the intra-asphalt, left-lateral shear component, complementary tensional features reminiscent of right-lateral offset can be detected along the edge of the road where the asphalt meets the grass verge (Figs. 1 and 2). In this case, however, and contrary to the intra-asphalt, left-lateral dislocation, the asphalt seems to have been fairly well attached to the rough edge of the road and grassy verge, and the tensional features there are the result of drag rather than dislocation. This is also evident from the fact that the asphalt has slipped downhill by 33–35 cm closest to the prominent, intra-asphalt offset, whereas the slippage diminishes to 3–5 cm adjacent to the grass verge.

3. Asphalt loading conditions

The new asphalt layer has a thickness of ca. 3 cm. It was laid down in August 1995 upon an older, more indurated, worn-down metalled surface, and it was laid during showery weather. Before laying the new asphalt layer, a primer—a type of emulsion or 'glue'—consisting of 50% bitumen and 50% water was applied to the old surface. Rain at the time may have had the effect of allowing the formation of a thin film of water between the hardening emulsive layer and the new asphalt carpet, thus reducing the adhesive and bonding properties of the new asphalt along this interface. Once initiated, this surface of weakness would have had the potential to function as a décollement; yet the ultimate slippage, aided by gravitational forces, apparently came several months later, perhaps during the hot days of early summer in the following year after several, diurnal, freeze–thaw cycles. This is deduced by the fact that the road-parallel, longitudinal white lines on the asphalt surface, which can be seen especially well in Fig. 1, were caused by a snowplough—and these scratch marks are themselves bent or offset, presumably coeval with the gravitational slip and strike-slip deformation in the asphalt layer. Once separation along the curved rupture (Fig. 1) was initiated—though the precise reasons for this rupture are unknown—then the gravitational forces acting on this narrow strip of asphalt above its interface décollement

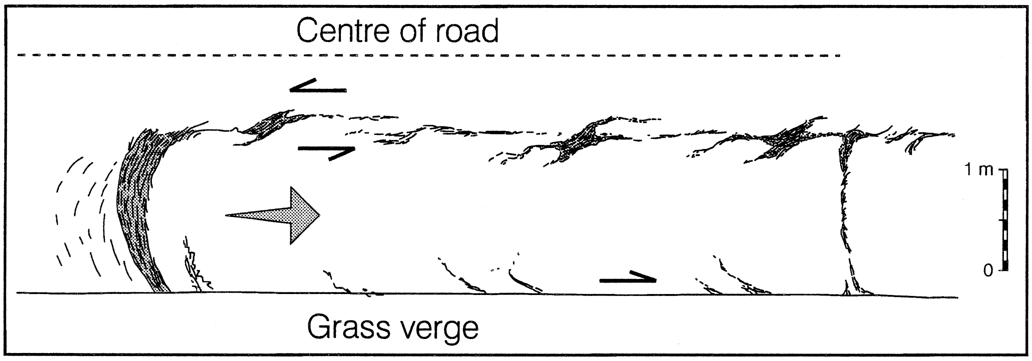

Fig. 2. Line drawing of the deformed road surface, based mainly on field measurements and, in part, on the photographs. The grey-tone, large arrow indicates the direction of slip of the detached asphalt. Sense of slip at the asphalt margins is shown by the semi-arrows.

Fig. 3. The same structures as in Fig. 1, but looking uphill towards the rupture scar. The oblique 'faults', at a moderate angle to the sinistral principal deformation zone, and the dark, rhombohedral, transtensional areas akin to pull-apart basins, are easier to recognise as such from this photographic angle.

Fig. 4. The 'faults' and pull-apart 'basins' along the strike-slip dislocation just above the secondary, transverse rupture, ca. 7 m downhill from the main rupture; looking downhill.

Fig. 5. A close-up of one of the pull-apart 'basins' that developed along the sinistral, strike-slip dislocation in the asphalt. The pencil measures ca. 15 cm.

would have led to gradual downhill creep which assisted in producing the fascinating left-lateral slip and pull-apart stepover structures in the road surface.

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