CONTINENTAL SUBDUCTION IN THE NORTHERN U.S. ROCKIES — A MODEL FOR BACK-ARC THRUSTING IN THE WESTERN CORDILLERA

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ABSTRACT

Back-arc thrusts such as those of the western Cordillera are difficult to explain mechanically as overthrusts resulting directly from oceanic subduction, which would require transmission of tectonic stress through the weak magmatic core of the orogen. Also, increasing of basement rooting of major thrusts requires a reassessment of models of gravitational tectonics by spreading or gliding.

A model of westward subduction of the relatively heavy continental lithosphere beneath the geoclinal edge of the continent eliminates the problem of stress transmission. Eastward migration of underthrusts occurs both through the basement and along supracrustal decoulement surfaces. The developing thrust belt inherits ancient transverse faults in the continental crust as well as the arcuate outlines of the old geoclinal hinge. In southwestern Montana paired thrust belts reflect paired Paleozoic hinges. Tectonic and topographic highlands in the rear of the thrust belt, to which widespread synorogenic conglomerates bear testimony, result from great uplift due to the buoyance of subducted crustal slices that became decoupled from the sinking upper mantle in the hot core of the orogen.

The petroleum potential of the foreland thrust belt in southwest Montana, and perhaps elsewhere as well, must be evaluated in terms of basement rooting of at least some of the thrusts and of significant changes in facies and structural patterns across east-west faults.

INTRODUCTION

The kinematics and dynamics of large scale “foreland” or “back-arc” overthrusting have long constituted a major problem in geotectonics. In the years preceding and shortly after World War II such thrust belts were variously seen as a by-product of (1) continental collision and underthrusting (Argand, 1924; Kober, 1923), or a related concept referred to as “Unterstromung” or underflow in the European literature (Ampferer, 1923, 1924; Kraus, 1951); (2) the final collapse of elongate crustal downbuckles or “tectogenes” (Vening Meinesz, 1933; Griggs, 1939; Umbgrove, 1947); or (3) gravitational tectonics, either by shallow gliding (Gignoux, 1948, 1950; Tercier, 1950; de Sitter, 1950) or deep mass readjustments (van Bemmelen, 1932, 1933a, 1933b).

With the advent of modern global tectonics it became possible to reassess thrust belts in terms of horizontal plate motions. Thus, continent-directed thrusting in the Tethys belt could again be understood as a product of continental collision, much as it was in the heyday of continental drift, and recognition of pre-Mesozoic plate motions made it possible to apply this model to other orogens as well, including the Alleghanian and Hercynian in North American and Eurafrika. For asymmetric situations in which a continental mass is lacking on one side of the orogen, as in the case of the circum-Pacific belt, the new models returned to the notion of oceanic underthrusting once advocated by Umbgrove (1947) and now placed in the context of ocean spreading and subduction. This accounts well for ocean-directed thrusts on the oceanic side of the mobile magmatic arc, while the related concept of obduction can explain continent-directed thrusts involving oceanic rocks. What remained problematic, however, was the genesis of continent-directed thrust belts in the back-arc environment. Their position inland from structurally weak magmatic arcs (Fig. 1) makes it difficult to see these belts as still another product of ocean plate subduction, especially where distance from the continental edge amounts to hundreds of kilometers. The Cordilleran foreland thrust belt of western North America is a case in point. The general problem is here considered with this belt, and in particular its Montana-Idaho segment, as a test case.

BACKGROUND

More than 30 years ago, Eardley (1951, p. 311, 315, Fig. 176) pointed out that the eastern Cordilleran thrust front between Nevada and Alaska follows in a general way two great arcs with eastward convexity (Fig. 2). Elaborating on this observation and taking note of the spatial relation between the frontal thrust zone and the eastern hinge of the Proterozoic to Paleozoic geosyncline, I proposed a genetic model involving progressive underthrusting of a westward drifting North American craton beneath the eastern basement flank of the Cordilleran geosyncline (Scholten, 1956, 1957). Consideration of the problem of the transmission of forces led Misch (1960) to strong advocacy of the concept of continental underthrusting. In Canada, this concept was suggested by Bally, Gordy and Stewart (1966), who presented seismic evidence that the foreland thrusts are confined to the sedimentary strata of Proterozoic and younger age.