DAVID BLOOM

Time of initial thrusting in the Sevier orogenic belt, Idaho-Wyoming and Utah

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ABSTRACT

Reexamination of the distribution of fossils found in the earliest preserved synorogenic conglomerates within the Sevier thrust belt suggests that initial thrust movement may be no older than Aptian age. This interpretation is corroborated by subsidence analyses of sedimentary sequences lying within and east of the Idaho-Wyoming and Utah thrust belts. A major episode of middle Cretaceous (Aptian–Cenomanian) subsidence is interpreted as recording the initiation of thrust loading deformation in the adjacent Sevier orogenic belt. An earlier subsidence event took place during Middle Jurassic time, more than 30 m.y. prior to the Cretaceous event, and may be the result of tectonic events to the west that are unrelated to thrust deformation in the Idaho-Wyoming and Utah thrust belts. We find no verifiable evidence to support previous interpretations that Sevier belt deformation and uplift began in Late Jurassic time.

INTRODUCTION

The Sevier orogenic belt consists of a narrow zone of continuous structural disturbance that runs along the length of the U.S. Cordillera (Fig. 1). It was originally named for the Sevier arch in western Utah (Harris, 1959). Armstrong (1968) redefined the style and extent of deformation and referred to it as the Sevier orogenic belt. The belt consists of large-scale east-vergent thrusts and associated folds that lie between the "hinterland" to the west and the "foreland" to the east (Fig. 1). Although the hinterland is also characterized by thrust faults, it includes penetrative deformation and dynamothermal metamorphism (Snoke and Lush, 1984) not seen in the Sevier belt and therefore represents a discrete locus of tectonism to the west. Armstrong (1968) emphasized the Utah and southern Nevada sectors of the Sevier belt. However, thrust deformation associated with the Sevier orogeny can be traced northward at least into Wyoming, Idaho, and Montana (Armstrong and Oriel, 1965; Royse and others, 1975).

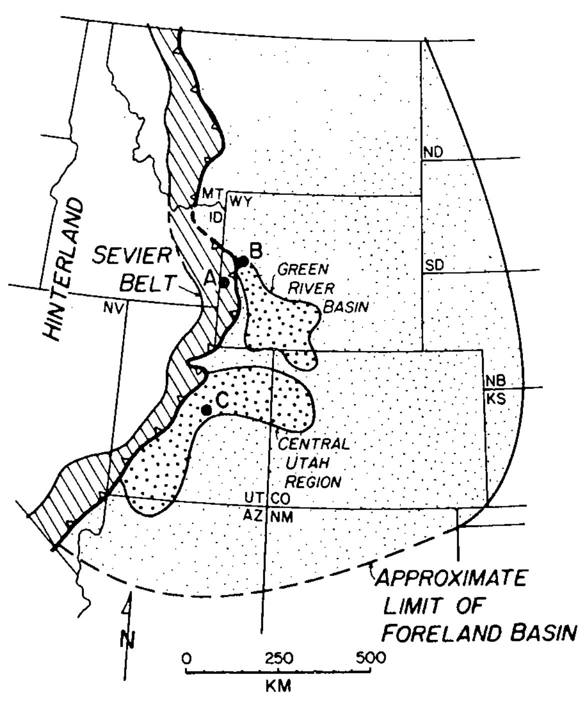

Figure 1. Generalized tectonic map of Sevier belt (ruled pattern), its foreland basin (light stipple), and Green River basin and central Utah region (heavy stipple) in Rocky Mountain region of United States. Large dots indicate localities of sections used in subsidence analyses A–C. Foreland basin strata shown in central Utah region occur in Uinta and Kaiparowits basins and Wasatch Plateau.

Shortening within the Sevier belt is inferred to have begun in latest Jurassic time and to have continued through earliest Tertiary time (Armstrong and Oriel, 1965; Armstrong, 1968; Wiltschko and Dorr, 1983); however, the timing of initial deformation has never been well established. Early accounts of the Sevier orogeny show the uncertainty in timing of the beginning of deformation. Discussions by Spieker (1946), Harris (1959), Armstrong and Cressman (1963), Armstrong and Oriel (1965), and Armstrong (1968) only suggested that deformation began during Early Cretaceous or *possibly* by Late Jurassic time. Unfortunately, the uncertainties of these earlier workers have been forgotten, and the Sevier orogeny is now commonly considered to have started during Late Jurassic time.

More recently, dating of synorogenic conglomerates along the Utah and Nevada sectors of the thrust belt indicates that Sevier deformation was probably no older than late Early (i.e.,

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middle) Cretaceous age. In central Utah, fauna of Albian and younger age have been reported from the lower part of the synorogenic Indianola Group conglomerates (Standlee, 1982; Lawton, 1985). Farther south, east of Las Vegas, Nevada, the oldest syntectonic deposits in the foreland basin (the Willow Tank and basal Baseline Formations) are also of Albian age (Bohannon, 1983). To the north, there has been no direct dating of the conglomerates of the synorogenic Kootenai Formation in western Montana. However, ages of units that bracket the Kootenai Formation (Peck and Craig, 1962; Suttner et al., 1981) indicate that this unit may be as young as Aptian age.

The purpose of this paper is to reevaluate critical data on the timing of thrust movement initiation in the Sevier orogenic belt in the Idaho-Wyoming region, which we interpret as having occurred no earlier than Aptian time. We test this interpretation by examining the subsidence history of the adjacent foreland basin in Wyoming and Utah.

AGE OF THE EPHRAIM CONGLOMERATE

The earliest thrusting event in the Sevier belt has traditionally been dated by fossils in the Ephraim Conglomerate (Fig. 2) near the Idaho-Wyoming border, which is interpreted as a synorogenic deposit shed from the uplifted and advancing Paris thrust sheet (Armstrong and Cressman, 1963; Armstrong and Oriel, 1965; Wiltschko and Dorr, 1983). The Ephraim Conglomerate consists, in places, of two members: a thin lower mudstone member of transitional marine to nonmarine origin (Eyer, 1969, p. 1377) and a thick upper conglomerate member that contains intercalated nodular limestone and mudstone beds (Mansfield, 1952). Fossil collections from both members of the Ephraim Conglomerate are limited.

Fossils from the lower mudstone member of the Ephraim Conglomerate include belemnites, scaphopods, and pelecypods collected by W. W. Rubey in the early 1930s at a few localities about 8 m above the base of the unit (Fig. 2; J. B. Reeside, 1934, unpub. U.S. Geological Survey rept.; Mansfield, 1952). These shallow marine fossils are similar to those found in the underlying Stump Formation of Late Jurassic (Oxfordian) age (Fig. 2). One of us (Bowdler) recently found foraminifera and associated glauconite preserved in the upper part of the lower Ephraim Conglomerate about 12 m below the basal conglomerate of the upper member at Salt River Pass, Wyoming (near site A, Fig. 1). The fossil assemblage includes at least seven species of benthic foraminifera of undetermined Jurassic or Early Cretaceous age. That the fossils are marine and are not abraded indicates that at least part of the section is of marine origin.

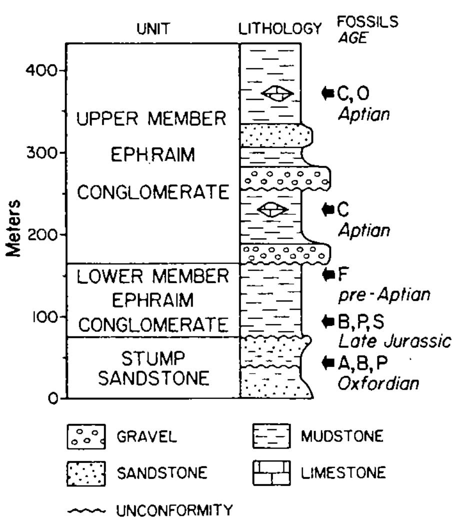

Figure 2. Lithology, thickness, and biostratigraphic age of Upper Jurassic and Lower Cretaceous deposits in Idaho-Wyoming thrust belt. Section is generalized but is representative of stratigraphic section in vicinity of site A (Fig. 1). Letters indicate important fossil localities. Fossil types: A = ammonites; B = belemnites; C = charophytes; F = foraminifera; O = ostracodes; P = pelecypods; S = scaphopods. Compiled from Eyer (1969), Furer (1970), Grambast (1974), Peck and Craig (1962), Pipiringos and Imlay (1979), and J. B. Reeside (1934, unpub. U.S. Geological Survey report).

In contrast, the overlying conglomeratic member of the Ephraim Conglomerate contains scarce fossils of nonmarine origin—charophytes and ostracodes of Aptian age (Peck and Craig, 1962; Eyer, 1969; Grambast, 1974). Although the age range of charophytes may be equivocal, the charophyte species (*Atopochara trivoluis* Peck) found in the upper member of the Ephraim Conglomerate is considered to be a good worldwide index fossil for Aptian nonmarine deposits (Peck and Craig, 1962). The fundamental problem is one of determining the age of the earliest conglomeratic bed within the Ephraim Conglomerate. We emphasize that the lower member lacks synorogenic gravel, represents marine deposition in part, and is compositionally distinct from and, at least in its basal part, much older than the upper member of the Ephraim Conglomerate. Most of these differences were recognized long ago by Mansfield (1952, p. 42). Therefore, ages from the lower member of the Ephraim Conglomerate have little meaning for dating the synorogenic conglomerate of the upper member.

Furer (1970) emphasized the abrupt change in composition between the lower and upper members of the Ephraim Conglomerate. There is a sharp decrease upsection in relative abundance of feldspar, phosphate, and chlorite (clay), with an attendant increase in abundance of chert grains and smectite. Furer (1970) correlated these compositional changes with those found in the Morrison Formation and overlying Cloverly Formation elsewhere in Wyoming, which may be separated by an extended hiatus of as much as 40 m.y. (Dodson et al., 1980). Whether or not the Ephraim Conglomerate represents continuous deposition from the base of the lower member to the top of the upper member is uncertain to us. The erosional surface at the base of the lowest conglomerate bed (Fig. 2) appears in places to be a major scour feature that has completely removed the lower mudstone member of the Ephraim Conglomerate (Pipiringos and Imlay, 1979). Possibly this contact represents a major unconformity or, alternatively, perhaps the entire section of Ephraim Conglomerate represents slow, episodic deposition, as is typical for fluvial systems. In either case, these fossils represent the only direct dating of the synorogenic upper conglomeratic member of the Ephraim Conglomerate. Fossils collected from the upper conglomeratic member of the Ephraim Conglomerate only constrain the initial timing of the thrust-derived coarse-grained deposition as Aptian or perhaps slightly older. Such an interpretation is compatible with the Aptian-Albian age of widespread coarse-grained fluvial deposits found elsewhere in the foreland basin of the Sevier belt (see introduction).

SUBSIDENCE HISTORIES

The inference of a middle Cretaceous age for deformation in the Sevier belt, as determined from dating of synorogenic conglomerate, can be tested by analyzing the subsidence history of the foreland basin adjacent to the thrust belt. In recent years numerous studies have demonstrated that continental lithosphere responds either elastically or viscoelastically to emplacement of tectonic loads (e.g., Price, 1973; Watts and Ryan, 1976; Jordan, 1981; Beaumont, 1981). Although such studies vary in detail, taken together they provide a cohesive and powerful argument that the formation of foreland basins is a nearly instantaneous (10^5–10^6 yr; Turcotte and Schubert, 1982) mechanical result of load emplacement by the adjacent thrust plates and their attendant sedimentation. Simply put, the addition of excess mass by the emplacement of thrust plates *must* induce down flexure in the adjacent foreland area. Therefore, the timing of thrust load emplacements can be ascertained by analyzing the subsidence histories of basins near the thrust belt.

We have analyzed the Mesozoic subsidence histories of stratigraphic sections from intermontane basins within and just east of the Sevier belt in Wyoming and Utah (Fig. 1). Prior to

Laramide deformation the upper Mesozoic strata of these basins formed coextensive parts of the Sevier foreland basin. From these data we have plotted subsidence histories, following the method of Van Hinte (1978). At the same time, locally compensated components of subsidence caused by the weight of the immediately overlying sedimentary units were removed, as in an Airy-type isostatic model (i.e., backstripping) as discussed by Watts and Ryan (1976). We did not attempt to backstrip the data by using a flexural model that would take into account regional loading by the thrust plate and its eroded constituents. Our interest is only in the timing of subsidence and not the quantitative evaluation of different contributors that have caused the subsidence.

Data Bases

Composite stratigraphic sections and well-log information from the literature (see Appendix 1)[1] were used to compile stratigraphic data for each area. Compaction corrections used in backstripping were modified after exponential functions presented by Sclater and Christie (1980). Water depths were estimated by faunal assemblages or interpretations of depositional environments as follows: fully marine facies = 60 to 300 m, shallow marine facies = 0 to 60 m, and nonmarine facies = 0 to 300 m above sea level. At the scale of the diagrams in Figure 3, errors due to paleobathymetric estimates are small and are shown by the width of the subsidence curves. Sudden changes in the subsidence curves are artificially generated because of the lack of completeness of the paleobathymetric data and probably, in truth, represent more gradual transitions. Nonetheless, the total amount of subsidence at a site includes these changes in paleowater depth as well as changes in sedimentary thickness per unit of time. Results (Fig. 3A–3C) are presented as total subsidence (corrected for compaction) and tectonic subsidence (backstripped) curves for each area.

RESULTS

Jurassic Subsidence

The curve generated from the Crawford thrust sheet section shows a period of rapid subsidence that took place during Middle Jurassic time (Fig. 3A). To the east of the thrust belt (Fig. 3B, 3C) there was very little subsidence during this time in comparison to the Cretaceous event. Middle Jurassic subsidence probably reflects a tectonic event that took place much farther west than the Sevier belt. This probability is indicated by (1) an absence of coarse clastic material in units of this age (the Arapien Shale and Carmel Formation in Utah and the Twin Creek Formation in western Wyoming; Imlay, 1980), suggesting that there was no local thrusted-highland source area, and (2) the limitation of subsidence to the thrust belt stratigraphic sequences while the foreland region to the east was not significantly affected. Possible subsidence mechanisms include thermal subsidence after the Middle Jurassic thermal metamorphic event in and around northeastern Nevada (Snoke and Lush, 1984) and/or flexural subsidence as a result of the emplacement of thrust plates in Nevada and northwestern Utah (e.g., Allmendinger et al., 1984). Any of these orogenic events to the west of the Idaho-Wyoming and Utah thrust belts may have been capable of producing at least local lithospheric subsidence.

Middle Cretaceous Subsidence

After the Jurassic subsidence event there was an extended hiatus during which very little net subsidence took place. If the thrust belt had been actively uplifting and shedding sediment into the adjacent foreland basin during Early Cretaceous time, we would expect to see a record of sedimentation and not an unconformity. Although there is no record of the subsidence history of the foreland basin during the hiatus, we know that the last rocks preserved beneath the unconformity (the Morrison Formation and equivalents) and the first rocks above the unconformity (the Cloverly Formation and equivalents) both represent low-gradient fluvial deposition probably 100 m or less above sea level. Hence, little net subsidence could have taken place during the hiatus. If, instead, the foreland basin had continued to subside below sea level during the hiatus, there would have been deposition of marine sediments or, in the case of nondeposition or slow sedimentation rates, the development of substantial paleobathymetric relief prior to the resumption of deposition. The preserved stratigraphic record shows no evidence of marine deposition during this period nor a marked increase in paleobathymetry following the unconformity in the section. Therefore, the most

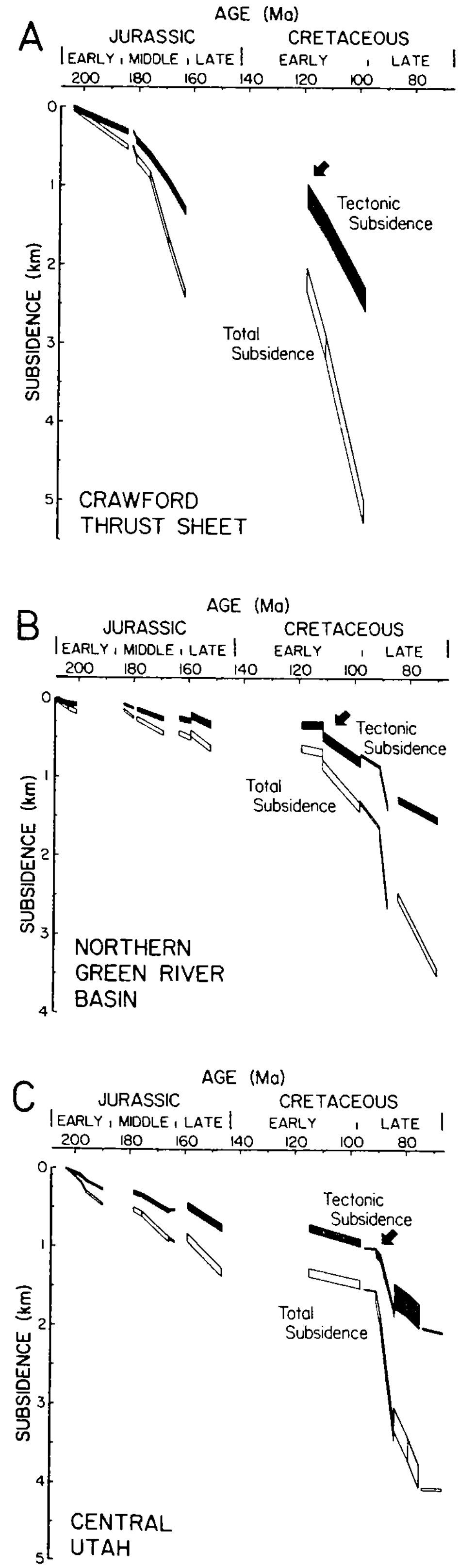

Figure 3. Total and tectonic subsidence curves for Jurassic-Cretaceous stratigraphic sections in foreland of Sevier belt. Location of sections shown in Figure 1. A: Crawford thrust sheet; B: northern Green River basin; C: central Utah area. Hiatuses are shown by gaps in subsidence curves. Aptian–Cenomanian time span is 119–91 Ma. Arrows point to inferred beginning of rapid subsidence during middle Cretaceous time. Sources of data for each section described in Appendix 1 (see footnote 1). Time scale from Palmer (1983).

[1]Appendix 1, Location, data, and references for stratigraphic information used in subsidence analysis, GSA Supplementary Material 8607, is available on request from Documents Secretary, Geological Society of America, P.O. Box 9140, Boulder, CO 80301.

likely interpretation is that there was no significant subsidence during the hiatus.

During Aptian to Cenomanian time there began to be a marked increase in the rate of subsidence within the Sevier foreland. The total magnitude of tectonic subsidence after this time in each stratigraphic section analyzed (Fig. 3) exceeds 1 km. Rapid subsidence was accompanied by an influx of coarse detritus derived from the west and deposited in nonmarine, deltaic, and shallow-marine environments; hence, relative proximity to an uplifted source area to the west is indicated. In Wyoming the subsidence began in Aptian-Albian time (119–97.5 Ma); in Utah the subsidence began in Albian-Cenomanian time (113–91 Ma). These times are coincident with the age of the earliest synorogenic conglomerate in the thrust belts of Wyoming (the upper Ephraim Conglomerate of Aptian age) and Utah (the basal Indianola Group of Albian age).

INTERPRETATION AND CONCLUSIONS

We interpret this rapid increase in subsidence to be the result of the initiation of faulting in the Idaho-Wyoming and Utah thrust belts. Tectonic loading by thrust sheets and attendant sedimentation would induce more than 4 km of subsidence in the adjacent foreland basin by the end of Cretaceous time (Jordan, 1981). Field studies in the thrust belt (Armstrong and Oriel, 1965; Royse et al., 1975) indicate that the first deformation of the Sevier orogeny was movement of the Paris thrust sheet. There is no evidence that this deformation took place before Aptian time. Because the Jurassic and Cretaceous subsidence events are separated by more than 30 m.y., we interpret these two events as distinct responses to possibly unrelated tectonic episodes. Therefore, we feel there is as yet no unequivocal evidence for pre-middle Cretaceous thrust loading related to deformation of the Sevier belt as defined by Armstrong (1968). Such a revision of the timing of initiation of the Sevier orogeny may necessitate a reevaluation of the possible driving mechanisms for this event.

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