Pergamon

Journal of Structural Geology, Vol. 16, No. 3, pp. 371 to 380, 1994
Elsevier Science Ltd
Printed in Great Britain
0191–8141/94 $06.00+0.00

Geometry of an outcrop-scale duplex in Devonian flysch, Maine

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(*Received* 21 *April* 1992; *accepted in revised form* 22 *May* 1993)

Abstract—We describe an outcrop-scale duplex consisting of 211 exposed repetitions of a single bed. The duplex marks an early Acadian (Middle Devonian) oblique thrust zone in the Lower Devonian flysch of northern Maine. Detailed mapping at a scale of 1:8 has enabled us to measure accurately parameters such as horse length and thickness, ramp angles and displacements; we compare these and derivative values with those of published descriptions of duplexes, and with theoretical models. Shortening estimates based on line balancing are consistently smaller than two methods of area balancing, suggesting that layer-parallel shortening preceded thrusting.

INTRODUCTION

The study of regional-scale duplexes in thrust belts (for example, Dahlstrom 1969, Boyer & Elliott 1982) is hindered by the need to map large areas in rugged terrane, spotty exposure, equivocal rock-unit assignments and by lack of subsurface information. Understanding of duplex geometry and evolution can also be gained through careful study of outcrop-scale examples. Small duplexes have been described or noted from many orogenic belts (e.g. Cooper *et al.* 1983, Bosworth 1984, McClay & Insley 1986, Platt & Leggett 1986, Bowler 1987, Shanmugam *et al.* 1988, Phillips 1989, p. 178, Lewis & Ross 1991, Tanner 1992). Here we illustrate a classic example of a duplex in the Devonian flysch of the Acadian orogen in Maine (Bradley & Bradley 1988), one sharing more in common with natural examples than with the idealized models of Boyer & Elliott (1982) (Fig. 1) or Mitra (1986). Detailed mapping has enabled us to measure accurately parameters such as horse lengths and thickness, ramp angles and displacements; we compare these and derivative values with those of theoretical models. Shortening estimates based on line balancing and area balancing provide a basis for comparing these alternative methods. Our results, in addition, are consistent with stratigraphic evidence that early tectonic transport direction in northernmost Maine was dextrally oblique with respect to the main Acadian structural grain.

GEOLOGIC SETTING

The duplex occurs in the Connecticut Valley–Gaspe basin (Fig. 2a), a major structural sedimentary basin that extends about 1200 km along the strike of the northern Appalachians. The basin was deformed and metamorphosed during the Acadian orogeny, which occurred

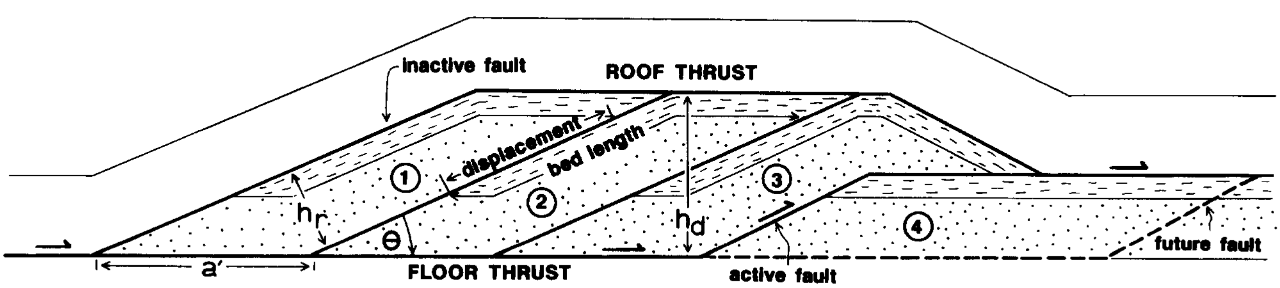

Fig. 1. Geometric model of a standard duplex showing growth of the duplex by repeated footwall failure at the leading edge, adapted from Boyer & Elliott (1982). Circled numbers identify horses in their palinspastic order and correspond to the sequence of displacements on the leading thrust bounding each horse. Half arrows mark active faults. Variables mentioned in the text also are shown. The final fault spacing (a') is the distance between the trailing branch points of two consecutively numbered horses. a' is positive in most cases (e.g. horses 20 and 21 in Fig. 3), but it is negative where the trailing branch point of a horse lies forward of the trailing branch point of the next higher numbered horse (e.g. horses 25 and 26).

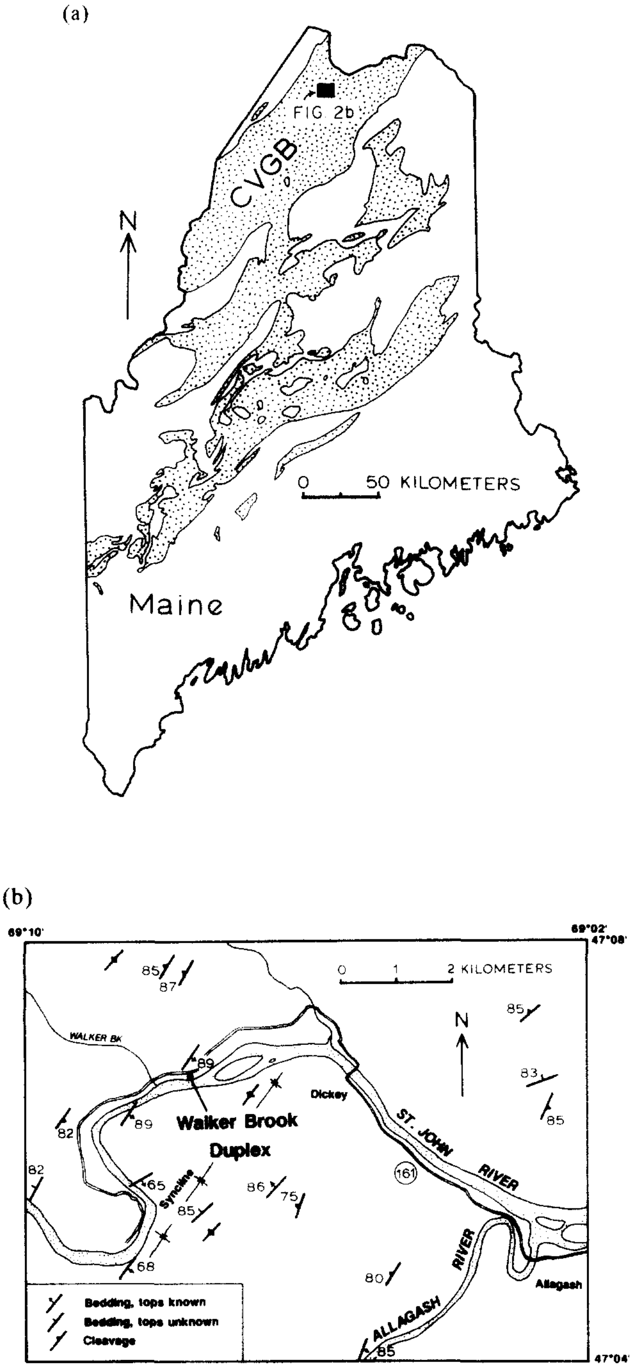

Fig. 2. (a) Map of Maine showing distribution of Acadian synorogenic clastic rocks (uppermost Silurian and Devonian) and location of the study area. CVGB is Connecticut Valley–Gaspe basin. Adapted from Osberg *et al.* (1985). (b) Part of the Allagash 15′ quadrangle showing location of Walker Brook duplex on the western limb of a kilometer-scale tight to isoclinal syncline. Entire map area is underlain by the Lower Devonian Seboomook Group. Compiled from Roy *et al.* (1991) and our own mapping.

during the Middle Devonian in the area of study in northern Maine (Bradley 1987) (Fig. 2b). The regional structure of the study area is dominated by tight to isoclinal folds with wavelengths up to a few kilometers (Roy *et al.* 1991). Mean regional strike is about 040°. Bedding dips steeply to subvertically. Enclosing strata are cut by a penetrative, subvertical pressure solution cleavage which has been described by Stringer & Pickerill (1980). Lower greenschist-facies metamorphic minerals include chlorite and fine-grained white mica.

The duplex occurs near the basin axis, within Lower Devonian turbiditic metapelite and metasandstone (the prefix *meta-* is omitted below) assigned to the St. John River Formation (informally defined by Hanson in Roy *et al.* 1991) of the Seboomook Group (of Pollock 1987). Deposition of the Seboomook Group immediately preceded and was terminated by the Acadian orogeny. The Seboomook Group represents flysch that was deposited in a now-deformed part of the Acadian foredeep (Bradley 1983, 1987). In the study area, the Seboomook Group consists of roughly equal proportions of: (1) sandstone turbidites (submarine fan facies A, B, C and D of Mutti & Ricci-Lucchi 1972); (2) pelite—originally mud-turbidites—of slope and (or) basin-plain origin; and (3) pelite-dominated olistostromes (facies F of Mutti & Ricci-Lucchi 1972), containing soft-sediment deformation structures with contractional and sheath geometries.

WALKER BROOK DUPLEX

Overview

Walker Brook duplex is exposed at a large outcrop of the Seboomook Group along the north bank of the St. John River, a short distance downstream from the mouth of Walker Brook (Fig. 2b). We discovered the duplex in 1987 during the course of regional geologic mapping, and later returned to map it at a scale of 1:8 (Fig. 3), using tape, compass and a 1 m portable grid. The duplex is composed of a single turbidite bed (hence it is an 'internal duplex' as defined by McClay & Insley 1986), repeated at least 211 times. The exposed portion is about 1 m thick and 17 m long. Unfortunately, the front of the duplex is under water, and overburden covers the rear. The floor and roof thrusts and enclosing beds are essentially parallel, and all dip steeply to subvertically. The overall appearance is that of a cross-section through a thrust belt (Fig. 4a), tipped on edge so that what looks like a cross-section actually is a geologic map. The duplex is directly underlain and overlain by graded beds that young toward the southeast. The graded beds at the lower (Fig. 4b) and upper contacts with the duplex are replaced laterally by zones of phacoidally cleaved slate. Several smaller duplexes occur in younger strata a short distance to the southeast (L. Hanson oral communication 1989).

The repeated bed grades upwards from ripple-drift and convolute-laminated very fine sandstone (T_c Bouma division, maximum grain diameter about 0.1 mm) into dark, laminated siltstone and pelite (T_{de}). The lower bedding-parallel detachment is at the graded base of the sandstone; the upper detachment occurs within pelite at the top of the graded couplet. The bed thickens systematically in the direction of thrust motion from about 0.07 to 0.12 m (mean 0.091 m). There is considerable thickness variation between some adjacent slices that cannot

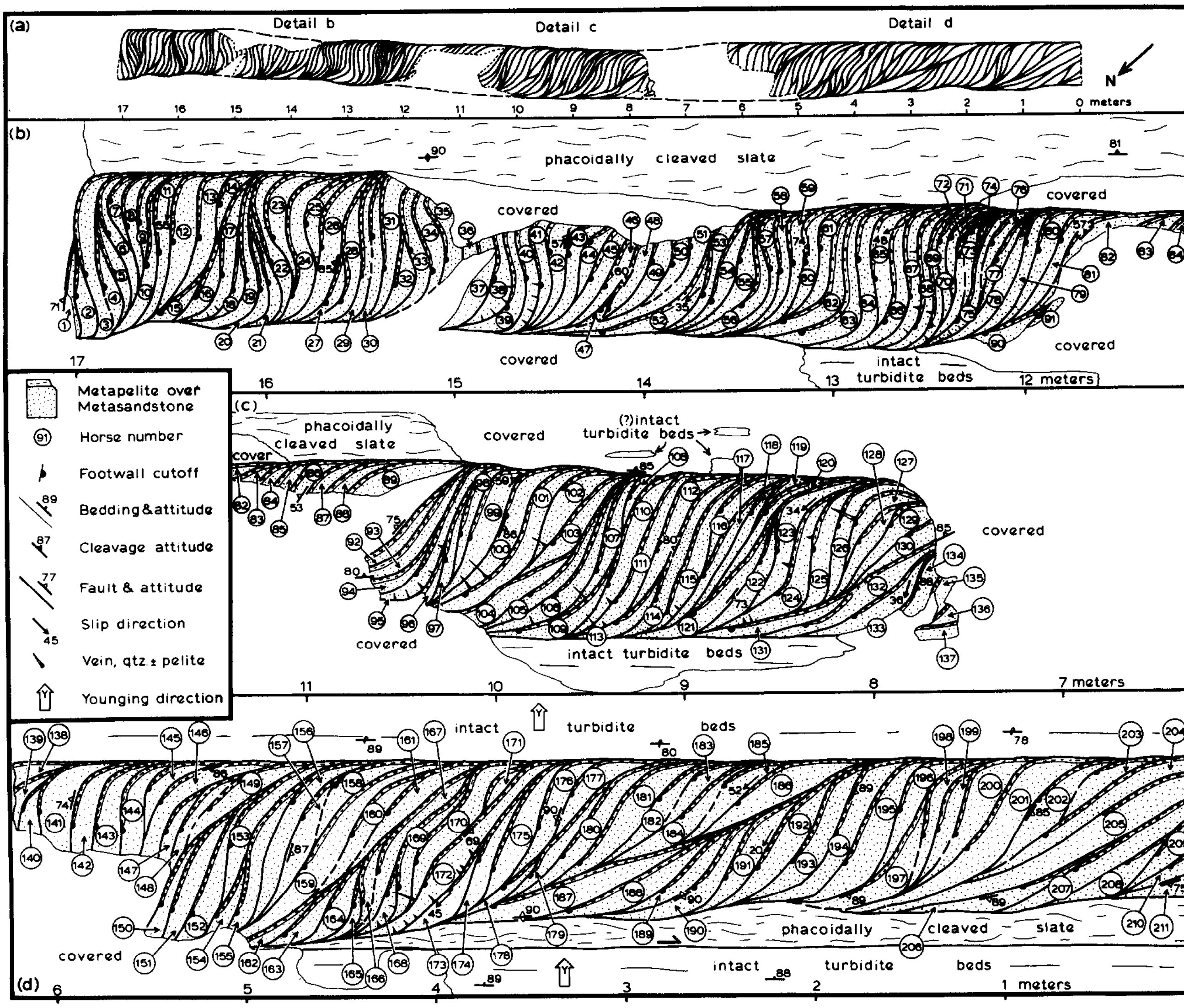

Fig. 3. (a) Simplified map (original mapping scale was 1:8) of Walker Brook duplex, near Allagash, Maine, showing fault traces and location of detailed geologic maps (b–d). The 1-m thick duplex consists of a single 10-cm thick turbidite bed repeated at least 211 times along an outcrop length of 17 m. Striae on fault surfaces indicate oblique transport, up and to the right. Corrected for obliquity, we estimate 95 m of shortening for the exposed portion of the duplex. Circled numbers show relative palinspastic position of horses.

be due to initial stratigraphic thickness variation (Fig. 5a). In the anomalously thick bed segments, probable thickening mechanisms are layer-parallel shortening (especially beyond the duplex front; see below) and displacement on obscure sandstone-on-sandstone thrusts. The anomalously thin segments probably are missing their bases, owing to close initial spacing between thrusts.

Pre-folding age of duplexing

Faulting occurred in strata that were flat-lying and at least partly lithified. Evidence for pre-duplex lithification is provided by extensional quartz veins in sandstones that fan around the convex outer arcs of fault-bend synclines (Figs. 3, 4c and 6e & f). The quartz was later recrystallized during low-grade regional metamorphism, but it contains relict inclusion trails that reveal an originally fibrous texture. Most veins cut a single bed and terminate upward in less competent pelite (Fig. 3); a few cut several horses. The pelite was sufficiently mobile at the time of faulting to be injected a few cm upward into the bases of some veins. Some pelite injections (e.g. in horses 102, 111 and 168) are bounded below by sandstone and hence are rootless, owing to continued fault motion after pelite injection. Although Walker Brook duplex occurs on the limb of a regional fold, a flexural-slip origin is unlikely (cf. Tanner 1992) because the link thrusts are perpendicular to the orientation predicted by the flexural slip model.

Transport direction

Kinematic analysis of deformed early faults is akin to paleocurrent analysis in deformed strata (Bradley 1989). In the present study, we removed the effects of Acadian regional folding by simple tilt-correction about bedding strike (attitude 216° 89°W). Although bedding–cleavage intersections near the duplex indicate that regional folds locally plunge about 25° to the southwest, we intentionally did not apply any special plunge correction. The standard stereographic plunge removal procedure (remove plunge first, then restore bedding to horizontal by strike rotation: Ramsay 1961) implies a polyphase folding history about two mutually perpendicular axes that finds no support in the regional geology. It is far more likely that the plunge developed as the folds tightened; tilt-correction about bedding strike approximates this folding history quite well for gentle plunges.

In the stratigraphic reference frame, contractional faults within the duplex strike northwest and mostly dip northeast; a few are overturned to the southwest (Fig. 6b). Slickenlines on fault surfaces plunge moderately to the east in the stratigraphic reference frame (Fig. 6d). Therefore, the duplex originally was a sinistrally-oblique, W-directed thrust zone (Fig. 7). The mean transport direction was 275°.

In most studies of thrust tectonics, cross-sections are drawn perpendicular to strike, and transport direction is assumed or known to be parallel to the plane of section. Geometric analysis of Walker Brook duplex is complicated because the map view is perpendicular to faults, yet the transport direction makes an angle of about 44° with the section plane. If Fig. 3 were redrawn with the transport direction parallel to the page, however, fault surfaces would intersect the section at 46°. Most of the parameters of interest (for example, ramp height, horse length and ramp angle) are most readily analyzed and compared with other studies when the faults themselves are normal to the plane of section. Accordingly, the ensuing analysis is based on planimetric measurements taken directly from Fig. 3. In the discussion of shortening, we also give results subject to correction for obliquity of the section.

Palinspastic position of horses and sequence of thrusting

The horses (and corresponding leading faults) in Fig. 3 are numbered 1–211 in palinspastic order. Two assumptions allow unambiguous numbering of all horses: (a) all faults shortened bedding; and (b) a single bed has been repeated. We determined the palinspastic order by visually matching pelite–sandstone cut-offs in the hangingwall and footwall. Most of the matches are obvious, and even the slightly problematic matches are unique. For horse 14, for example, there are possible cut-off matches with the horses labeled 17, 16 and 15, but only the horse labeled 15 uniquely meets conditions (a) and (b) above; the other two possibilities would leave out one or more horses from a restored section.

The distribution of leading and trailing branch points (Boyer & Elliott 1982) suggests that the duplex formed by a combination of in-sequence displacement on the smaller displacement faults, and in-sequence plus out-of-sequence displacement on the larger faults. In the standard duplex of Boyer & Elliott (1982), all leading branch points occur at the roof thrust, and all trailing branch points occur at the floor thrust (Fig. 1). Figure 3 shows the more complex distribution of branch points in Walker Brook duplex. Only about half of the branch points lie along the roof or floor thrust; the remainder occur somewhere between the floor and roof and could be called anomalous. Bowler (1987) and Fermor & Price (1987) noted anomalous branch points in other duplexes, which they attributed to the termination of horses in the third dimension. This explanation seems reasonable for certain isolated anomalous branch points at Walker Brook, such as the leading branch points of horses 18, 62, 66, 78 and 160. About 10% of all branch points are probably due to termination of horses in the third dimension. Accordingly, it seems likely that horses were originally canoe-shaped in plan view.

Entire groups of anomalous branch points, however, appear to result from excess late displacement of particular thrusts. The straight fault between horses 186 and 187 illustrates this point. The trailing branch points of horses 180–186 all lie above the floor thrust of the duplex, whereas the leading branch points of horses 187–195 all lie below the roof thrust. Hangingwall antiforms in the horses below fault 186–187 are juxtaposed against footwall synforms in the horses above; fault 186–187, however, is unaffected by fault-bend folds above or below. Therefore, some displacement on the fault must postdate fault-bend folding. Restoration of about 1.5 m of displacement (out of a total 2.05 m) across fault 186–187 yields a standard duplex configuration with all branch points lying on the floor and roof thrusts. Accordingly, we suggest a simple two-stage faulting history for this part of the duplex. Initially, faults 180–195 formed by sequential footwall failure at the front of the duplex and moved in normal sequence. Displacement on fault 186–187 was about the same as on neighboring faults. Somewhat later, fault 186–187 underwent an additional 1.5 m displacement, doubling the thickness of the duplex and emplacing the former floor thrust over the former roof thrust. Other faults of excess displacement include 14–15, 130–131, 149–150, 161–162 and 177–178; each caused wholesale thickening of duplex. All of these larger faults juxtapose a series of trailing branch points in the hangingwall against a series of leading branch points in the footwall. Fault 14–15 was partly (but only partly) involved in the pronounced fault-bend folding of the horses immediately above and below.

Displacement estimates from restored sections

Four segments of the duplex, comprising horses 2–29, 54–81, 109–125 and 163–203, are well enough exposed that bed length and bed thickness (h_r) can be accurately measured. For these segments, we calculated apparent displacement (in the plane of Fig. 3) by comparing the present segment length (L_d) with restored bed lengths (L_o) determined by line balancing and area balancing. For line balancing, bed length (equivalent to horse length and to initial fault spacing) was measured along the sandstone–pelite contact. Bed length from each horse in a given duplex segment was summed to give the original bed length. For area balancing, the area of each

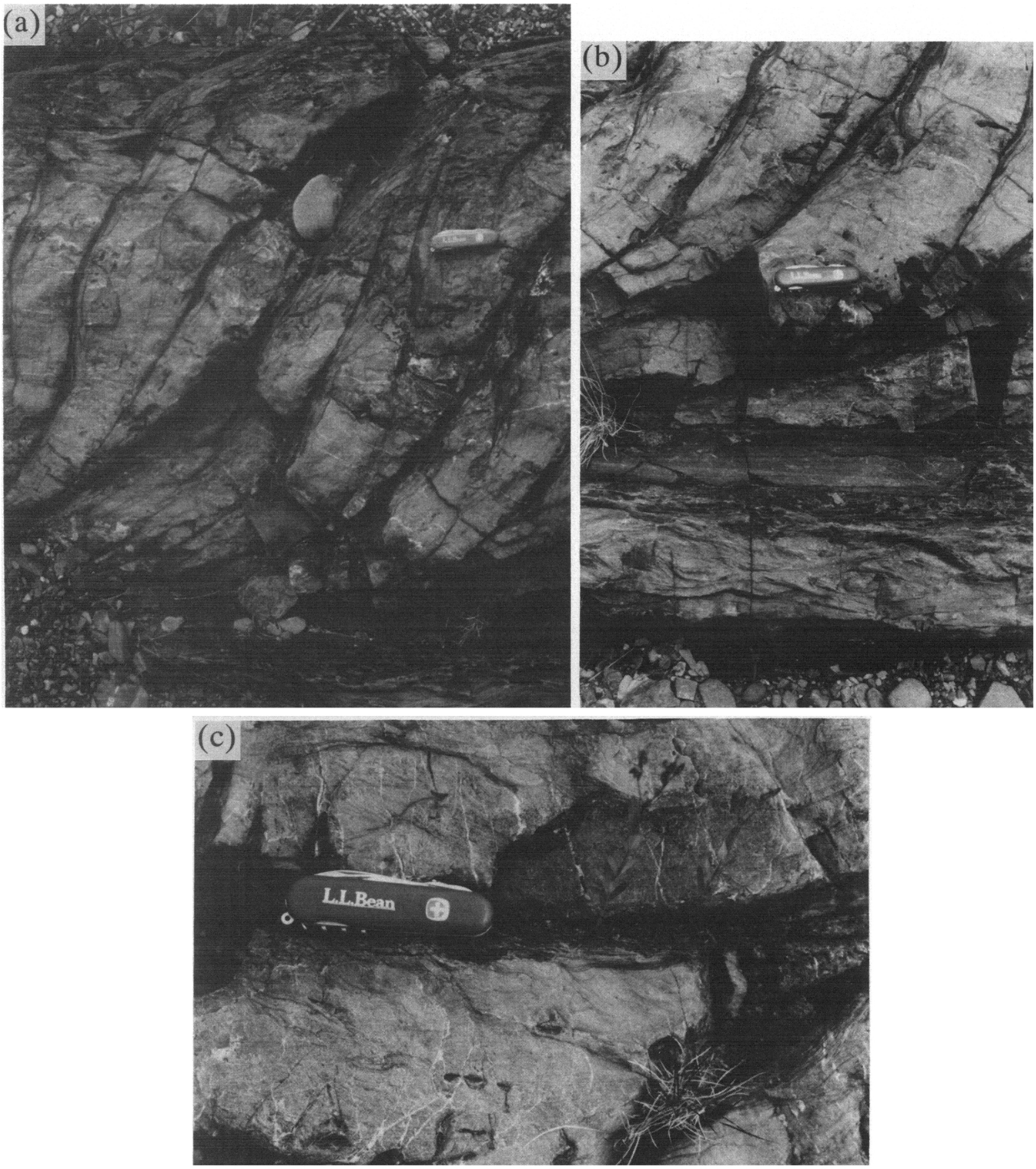

Fig. 4. Photographs of Walker Brook duplex. (a) Outcrop view of duplex. Lighter layers are metasandstone; darker layers are metapelite. Thrust transport was up and to the right. (b) Horses joining the floor thrust and underlying T_{cde} turbidite bed. Trailing branch points above the floor thrust mark a fault of excess displacement. (c) Quartz-filled extension veins that formed during fault-bend folding of already lithified sandstones.

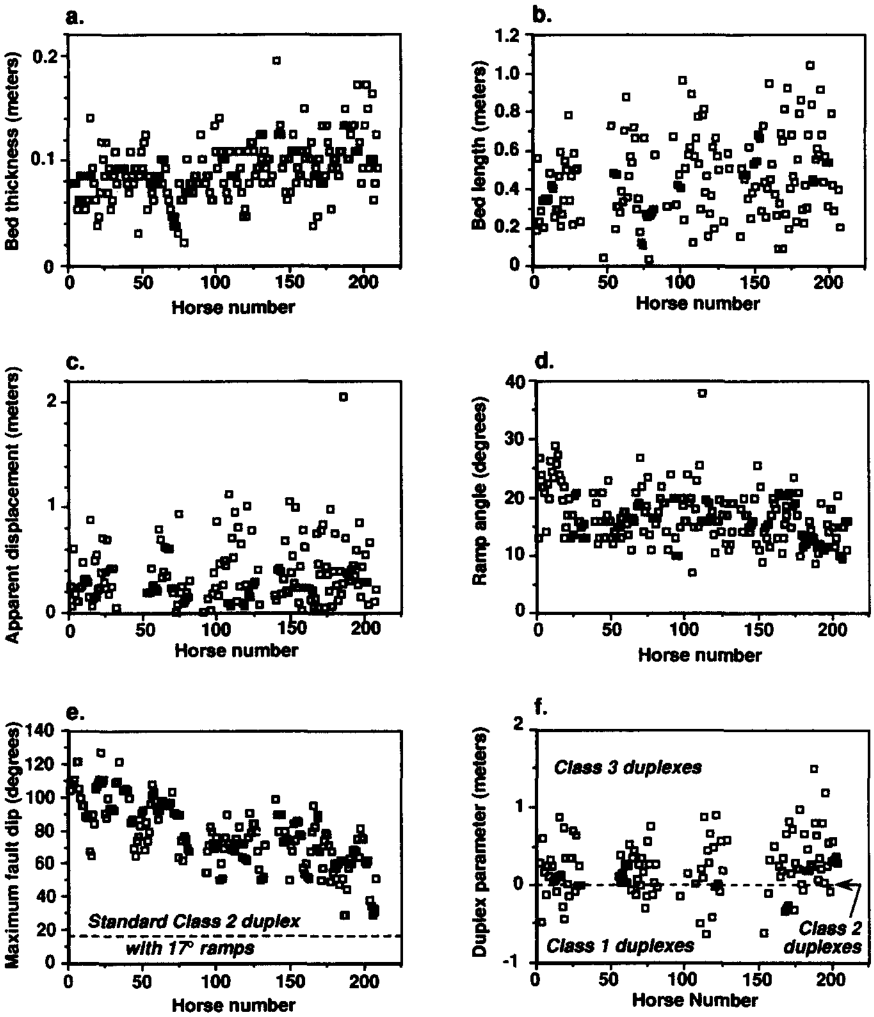

Fig. 5. (a) Bed thickness plotted against horse number, showing an increase in mean bed thickness in the transport direction. (b) Apparent bed length (equivalent to initial fault-spacing) plotted against horse number, showing considerable scatter (cf. the standard duplex in Fig. 1). (c) Apparent displacement plotted against horse number, showing considerable scatter. (d) Ramp angle plotted against horse number. The mean value is 17°; some steepening of ramps is observed toward the rear of the duplex. (e) Maximum apparent fault dip (in stratigraphic reference frame) plotted against horse number, showing a general decrease in fault dips in the transport direction. Fault dips from a standard duplex with 17° ramps would plot on the line shown. (f) The duplex parameter (cf. Mitra 1986) plotted against horse number. Each horse is bounded by leading and trailing faults, which have corresponding displacements of d_1 and d_2, respectively. Whereas most of the data plot in the Class 3 field, this plot shows all three of Mitra's duplex classes coexist intimately within Walker Brook duplex.

horse in a given duplex segment was summed to give the original area (equivalent to the term $h_d \times L_d$ below). We then calculated original bed length (L_o) from $L_o = h_d \times L_d/h_r$ (Hossack 1979). For the term h_r, we used the mean bed thickness for each corresponding duplex segment.

Results of the two procedures are compared in Table 1. Shortening estimates (natural strain, $\varepsilon = \ln(L_d/L_o)$) for the four segments range from -1.82 to -2.05 for line balancing, and a consistently greater -2.04 to -2.35 for area balancing (Table 1). In a detailed analysis of the Basse Normandie duplex in France, Cooper *et al.* (1983) found a similar discrepancy in shortening: line balancing suggested shortening of -0.22 (they expressed their results as percentages), whereas area balancing suggested shortening of -0.49. Cooper *et al.* (1983) attributed the 0.27 difference to layer-parallel shortening beyond the duplex tip, prior to thrust imbrication. Despite significantly greater shortening at Walker Brook, the *difference* between shortening estimates from line and area balancing ($\varepsilon = 0.31$, weighted mean) is virtually the same as in the French example. By analogy, we infer that early layer-parallel shortening played a role at Walker Brook.

Shortening across the entire duplex (regardless of gaps in the exposure or unrecognized horses) was evaluated by area balancing. The duplex was originally 149.8 m long and was shortened by 132.8 m (-2.18 natural strain), using values of 17.0 and 0.80 m for present duplex length and thickness, and 0.091 m for stratigraphic thickness (all lengths are apparent). True displacement is 184.6 m (apparent displacement times secant 44°).

Two potential sources of error merit discussion. In area balancing, stratigraphic thickness is generally measured in the undeformed foreland, but we could not measure an undeformed bed thickness because the front of the duplex is under water. Even though present and original bed thickness are undoubtedly different, the

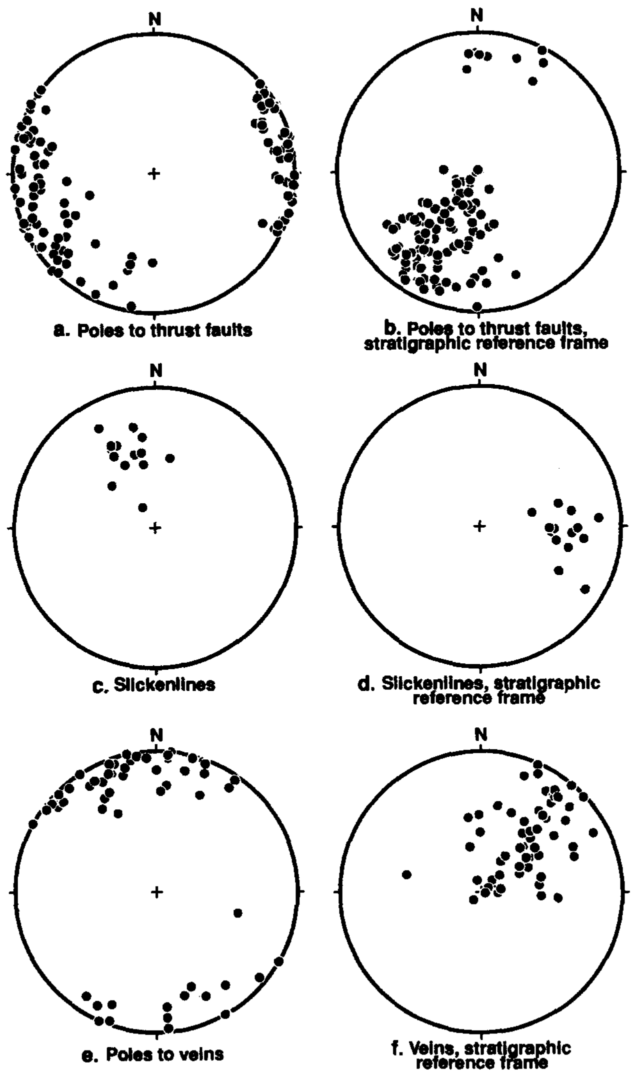

Fig. 6. (a) & (b) Stereoplots of poles to fault surfaces in Walker Brook Duplex, in the present and stratigraphic reference frames, respectively. (c) & (d) Stereoplots of fault lineations in the present and stratigraphic reference frames, respectively. (e) & (f) Stereoplots of poles to extension veins in the present and stratigraphic reference frames, respectively. The veins formed on the concave sides of hangingwall beds during fault-bend folding. Veins are filled with quartz; some have been injected by pelite near the subjacent fault. All plots are lower-hemisphere equal-area projections.

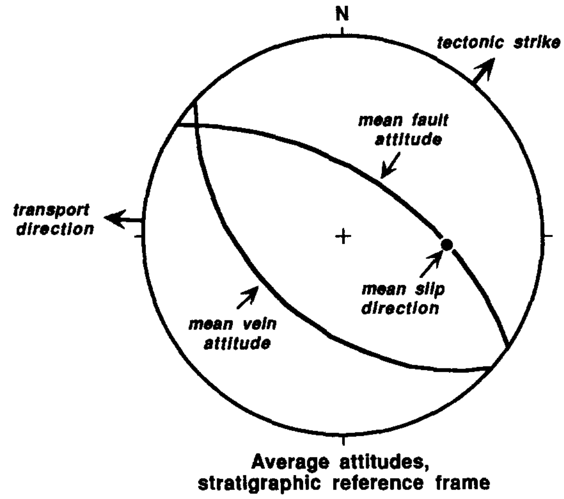

Fig. 7. Summary stereoplot showing mean attitudes of faults, slip lineations and extension veins in the stratigraphic reference frame. Thrust transport was toward the west, sinistrally oblique with respect to fault surfaces, but dextrally oblique with respect to mean tectonic strike. Lower-hemisphere equal-angle projection.

contributing factors are partly offsetting. Thus, beds were probably thickened by layer-parallel shortening beyond the duplex front, whereas steeply rotated beds to the rear are more likely to have been thinned during duplexing. Conversely, regional folding would have thinned beds at the duplex front that were oriented at a low angle to cleavage, while thickening beds farther back in the duplex that were oriented at a high angle to cleavage. Another potential source of error is the 44° angle between the transport direction and the plane of section. Out-of-plane movement would not be a problem if every horse were 'cylindrical', bounded by parallel branch lines along the floor and roof thrusts. Juxtaposition of non-cylindrical horses, however, could yield unrepresentative values of duplex height and cumulative bed length, leading to respective errors in the area and line balancing calculations. This is probably not a significant source of error because the large number of horses should even out any would-be variations resulting from juxtaposition of, for example, the non-cylindrical parts of two horses. In addition, although the horses are non-cylindrical, they are canoe-shaped rather than lozenge-shaped—hence minimizing any minor effect on area and line balancing results.

DISCUSSION

Comparison with other studies

The simplest and most widely understood model for duplex formation, referred to here as the standard duplex, was illustrated by Boyer & Elliott (1982) (Fig. 1). A standard duplex forms entirely by repeated, in-sequence failure of a frontal footwall ramp that links lower and upper detachments. Geometric properties of the standard duplex are numerous and precise: (1) floor and roof thrust are exactly parallel; (2) ramp angles are constant; (3) fault dips equal ramp angles; (4) all horses are exactly the same length; (5) displacements between horses are exactly twice the horse length; (6) tectonic thickening ratio (h_d/h_r in Fig. 1) is exactly 2; (7) natural strain is −0.69 (Cooper *et al.* 1983); and (8) all leading and trailing branch points lie along the roof and floor thrusts, respectively. The standard duplex is commonly portrayed with a kink-style geometry, although this may not be intrinsic to the model.

Walker Brook duplex is broadly similar to both the standard duplex of Boyer & Elliott (1982), and to the many published illustrations of regional-scale and outcrop-scale hinterland-dipping duplexes that are bounded by subparallel roof and floor thrusts (Boyer & Elliott 1982, Cooper *et al.* 1983, Bosworth 1984, Mitra 1986, Platt & Leggett 1986, Bowler 1987, Shanmugam *et al.* 1988, Phillips 1989, Lewis & Ross 1991, Tanner 1992). In detail, however, we note many differences

Table 1. Comparison between shortening estimates based on different methods

	Planimetric data*			Line balance calculations		Area balance calculations	
Horse numbers in segment	Length of segment (m)	Mean bed thickness (m)	Area of segment (m^2)	Shortening† (m)	Natural strain‡	Shortening (m)	Natural strain
2–29	1.49	0.078	1.26	9.42	−1.99	14.16	−2.35
54–81	1.66	0.069	1.26	9.21	−1.88	15.52	−2.34
109–125	1.11	0.087	0.904	7.55	−2.05	9.74	−2.28
163–203	3.43	0.107	2.89	17.70	−1.82	23.02	−2.04

* All values are apparent shortening in the plane of Fig. 3.
† $L_o - L_d$, where L_o is initial length of duplex segment and L_d is its present length.
‡Natural strain, $\varepsilon = \ln (L_d/L_o)$.

between Walker Brook duplex and the standard model. (1) Many horses at Walker Brook duplex have been back-rotated well beyond vertical. Although a few oversteepened horses are present in the regional-scale Tombstone 'multiduplex' (Canadian Rockies; Fermor & Price 1987) and in one small flexural-slip duplex in England figured by Tanner (1992), oversteepening is not observed in the other duplexes cited above. (2) About half of the branch points at Walker Brook lie between, rather than along, the floor and roof thrusts. As discussed above, we attribute this both to termination of canoe-shaped horses in the third dimension, and to out-of-sequence thrust reactivation. Among published examples, the Tombstone 'multiduplex' is most comparable to Walker Brook duplex in this regard. (3) The mean tectonic thickening ratio at Walker Brook duplex is 9.6 and shortening is −2.18 (natural strain). These values are the most extreme among the natural examples listed and are considerably greater than thickening and shortening values for the standard duplex (2 and −0.69, respectively). Some published examples (e.g. Basse Normandie duplex of Cooper *et al.* 1983) show substantially less thrust shortening than the standard duplex. (4) Link thrusts in Walker Brook duplex curve asymptotically into the floor and roof thrusts along a smooth (Cooper & Trayner 1986), rather than a staircase trajectory. This seems to be a common trait among all the natural examples cited above. (5) In all of the natural examples, including Walker Brook duplex, the thickness of horses, length of horses, initial or final fault spacing, displacements across link faults, and ramp angles are quite variable (Figs. 5a–e).

Mitra (1986) introduced a series of duplex models that begin to allow for some of the observed variations in natural duplexes listed in item (5)—variations in final fault spacing along the floor thrust (a'), and in differential displacements on the leading and trailing thrusts of a horse (d_2 and d_1, respectively) (Fig. 1). Mitra recognized three hypothetical classes of duplex corresponding to the value of what is here termed the duplex parameter: $d_1 - d_2 - a' + h_r \operatorname{cosec} \theta$. The duplex parameter is negative for Mitra's Class 1 duplexes (hinterland sloping duplexes and independent ramp anticlines), positive for Class 3 (foreland sloping duplexes and overlapping ramp anticlines) and zero for Class 2 ('true' duplexes with parallel floor and roof thrusts). The standard duplex of Boyer & Elliott (1982) is a special case of Class 2, in which both $a' = h_r \operatorname{cosec} \theta$, and $h_d = 2h_r$. The duplex parameter can be calculated for any pair of initially adjacent horses. At Walker Brook, where there are 81 such pairs with adequate exposure, our calculations show that 60% of the pairs of horses belong to Class 3 (maximum value 1.5 m), and ~20% to Class 1 (minimum value −0.6 m) (Fig. 5f). The remaining 20% fall in Class 2 (duplex parameter = 0 ± 0.1 m). These results are only approximate for two reasons. First, Mitra's models assume uniform values for h_r and θ, yet both are variable at Walker Brook (Fig. 5). Second, the leading horse needs to be restored (Mitra 1986, p. 1088) to eliminate any modifications during later thrusting to such variables as θ. Although we can restore all the horses to their original relative positions, we cannot quantitatively restore thrust-induced changes to h_r and θ. At appropriate values for Walker Brook duplex, however, these errors are relatively small. For example, to increase the duplex parameter by 10% would require a ~40% decrease in θ, or a ~65% increase in h_r. Taking the calculated values at face value, then, we conclude that all three of Mitra's classes coexist within Walker Brook duplex.

Regional geologic significance

Although duplex geometry was our main focus, results of the present study also bear on the nature of early Acadian deformation in this remote part of the Connecticut Valley–Gaspe basin. Partly lithified flysch of the Lower Devonian Seboomook Group was shortened by bedding-parallel thrusting, prior to the main phase of Acadian folding. Neither the stratigraphic throw nor the calculated shortening across the duplex are regionally significant, but the discovery of this small duplex suggests that other folded, bedding-parallel thrusts probably exist. If undetected, such thrust zones would lead to overestimates of stratigraphic thickness of the Seboomook Group, and underestimates of regional shortening across the basin.

Slickenlines clearly show that transport was directed toward 275° and was sinistrally oblique with respect to thrust surfaces. We do not know, however, whether this early tectonic transport direction: (1) is merely a local deviation like that noted by McClay & Insley (1986) for small duplexes in the Lewis thrust sheet in the Canadian Rockies; or (2) is a regional direction, which happens to be dextrally oblique with respect to the main Acadian structural grain. The second possibility finds some support from Acadian foredeep stratigraphy. Bradley (1987) and Ettensohn (1987) interpreted the diachronous pattern of Acadian foredeep clastic sedimentation from Gaspe to Virginia as evidence that the Acadian orogeny was diachronous, both across strike (younger toward the craton) and along strike (younger toward the southwest). This pattern suggests that the Acadian orogeny was a scissors-type collision and that relative motion had an approximately E–W trajectory of dextral oblique convergence with respect to the North American margin. Evidence for an early westerly transport direction at Walker Brook duplex is consistent with this scenario.

Acknowledgements—Field work for this study was done in 1987, and was funded by the COGEOMAP Program of the U.S. Geological Survey and Maine Geological Survey, by way of a grant to Lamont-Doherty Geological Observatory. We benefited from discussions with Lindley Hanson, Dave Roy, and Bob Marvinney in the field, and with Declan DePaor and Steve Boyer on thrust tectonics. Reviews by Alison Till, Diedre Bohn, Mark Evans, Steve Wojtal, and two anonymous reviewers substantially improved the presentation and logic. The stereoplots were done on Rick Allmendinger's STEREONET program for the Macintosh.

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