Tectonic significance of the Carboniferous Big Pond Basin, Cape Breton Island, Nova Scotia

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Detailed mapping in southeastern Cape Breton Island has revealed a strike-slip origin for the small Carboniferous outlier at Big Pond. Topographically low Carboniferous sedimentary rocks occur between splays of a previously unrecognized, northeast-trending set of high-angle faults, the Big Pond fault system. The section is dominated by fanglomerates, which coarsen toward the faulted basin margins and which were deposited and (or) reworked by currents flowing toward the basin's center and along its axis. We interpret the fanglomerates as syntectonic. Interbedded limestones of Visean age (Windsor B Subzone) provide age control for the upper part of the 300 m section and, by inference, for at least some of the fault motion. Dextral motion on the Big Pond fault system is indicated by (1) slickenside stepping directions on minor faults, which juxtapose basement against basement and which parallel the main northeast-striking fault; (2) northeast-striking mesoscale faults within the basin, which produce dextral offsets; and (3) shear and extension fractures in fanglomerate clasts along the northeast-striking basin margin faults, which reveal dextral and down-to-basin motion. The location of the basin at a right step in the through-going dextral fault system implies that it is a pull-apart basin. We suggest that during Visean times, southern Cape Breton Island was cut by several such dextral wrench faults and associated sedimentary basins and that the tectonic climate was similar to that recognized by previous workers in Newfoundland and New Brunswick. No evidence was found in support of the paleomagnetically based hypothesis for sinistral strike slip during this time.

La cartographie détaillée du sud-est de l'île du Cap Breton a révélé que la petite boutonnière carbonifère à Big Pond doit son origine à un décrochement. Les roches sédimentaires du Carbonifère des creux topographiques affleurent entre les ébrasements d'un ensemble de failles fortement inclinées et de direction nord-est, appelé le système de failles Big Pond, nonidentifié antérieurement. La coupe est dominée par des dépôts de cônes alluviaux de granulométrie croissante en direction des marges du bassin d'effondrement, et dont les matériaux furent déposés et (ou) remaniés par les courants s'écoulant vers le centre du bassin et le long de cet axe. Une origine syntectonique est attribuée aux dépôts de cônes alluviaux. Les calcaires interstratifiés d'âge du Viséen (sous-zone Windsor B) fournissent un contrôle sur l'âge de la partie supérieure de la coupe de 300 m et, delà, pour au moins une partie du mouvement de la faille. Le mouvement dextre du système de failles Big Pond est révélé par (1) les directions des termisaisons brutales des stries sur les plans de failles mineures qui opposent socle contre et parallèles à la direction générale nord-est de la faille; (2) des failles d'échelle moyenne à l'intérieur du bassin qui produisent des décalages dextres; et (3) le cisaillement et les fractures de tension au sein des fragments dans les dépôts de cônes alluviaux le long des failles de direction nord-est sur les marges du bassin, lesquels indiquent un mouvement dextre et jusqu'au bassin. La localisation du bassin décroché à droite par le système de failles dextres qui le traverse démontre qu'il s'agit d'un bassin d'expansion. Nous croyons que durant le Viséen, plusieurs failles de décrochement dextre et les bassins sédimentaires associés recoupèrent le sud de l'île du Cap Breton et que le contexte tectonique était similaire à celui évoqué par d'autres chercheurs pour Terre-Neuve et le Nouveau-Brunswick. Aucun indice n'a été observé qui appuierait l'hupothèse fondée sur le paléomagnétisme de failles de décrochement senestre durant cette période.

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Introduction

Like much of Atlantic Canada, Cape Breton Island is divided along steep faults into a series of basement uplands and lowlands, the latter of which are underlain by Carboniferous sedimentary rocks. Early workers (e.g., Bell 1938; Weeks 1954) assumed dip-slip displacement because old rocks are juxtaposed with young. On the other hand, subsequent studies indicated that motion on the two most important fault systems that cut the Canadian Appalachians—the Cabot and Minas systems (Fig. 1)—was mainly strike slip (Wilson 1962; Webb 1963, 1969; Belt 1968; Eisbacher 1969; Hyde 1979; Bradley 1982, 1984; Keppie 1982; Leger and Williams 1986). Webb's (1969, pp. 768–770) regional perspective led him to the reasonable suggestion that northeast-trending faults in southern Cape Breton Island were also dextral strike-slip faults, which

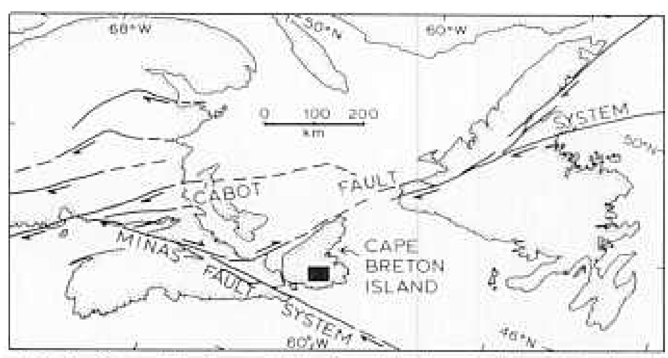

FIG. 1. Generalized map of the Canadian Appalachians showing the two major dextral strike-slip fault systems that were active during late Paleozoic times. Note the location of Cape Breton Island in the acute angle formed by the intersection of the Minas (equivalent to the Cobequid–Chedabucto and Glooscap faults and to the Minas Geofracture) and Cabot fault systems. Rectangle shows the location of Fig. 2.

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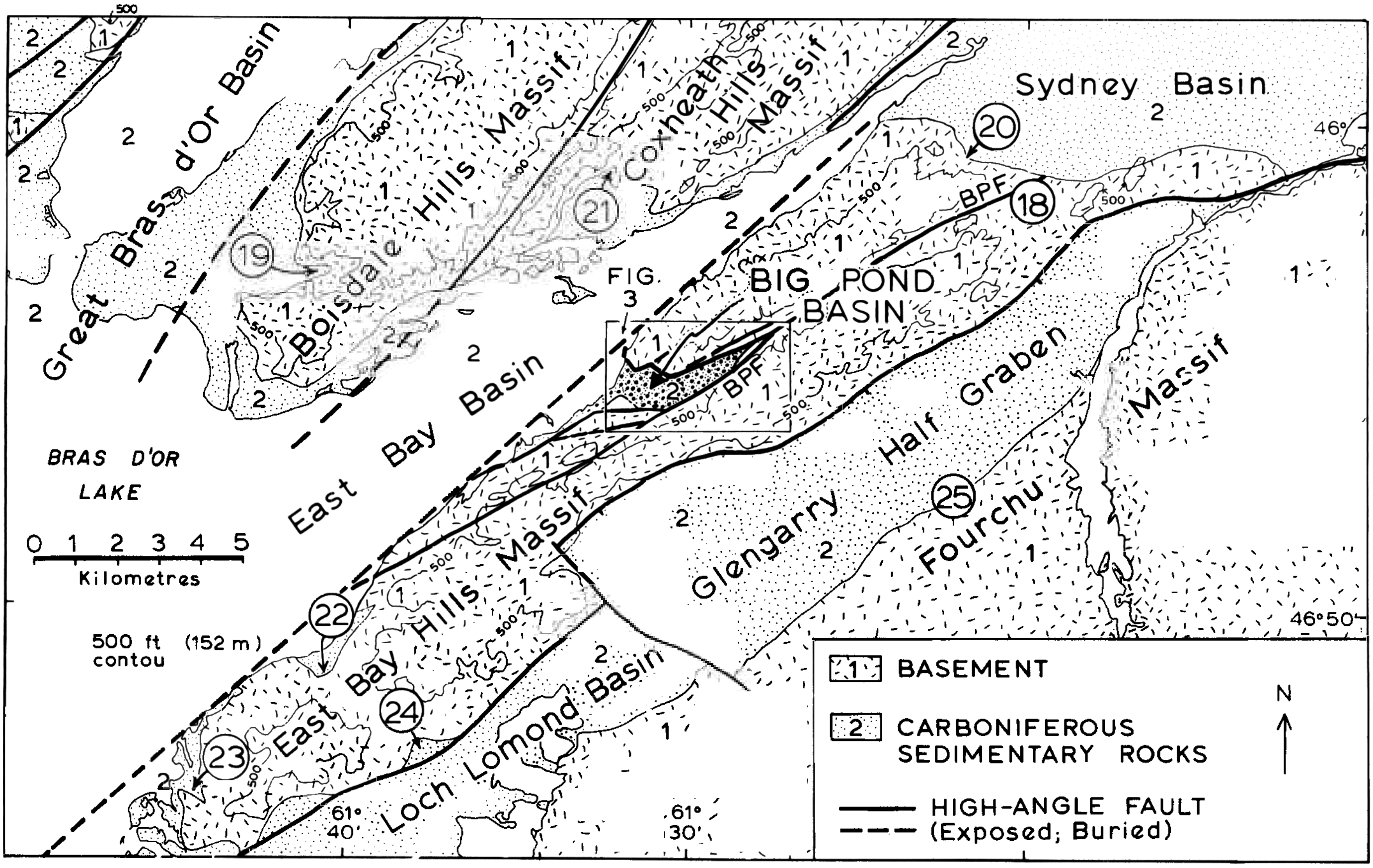

FIG. 2. Generalized geologic map of a portion of southeastern Cape Breton Island, showing the distribution of crystalline basement (locally with lower Paleozoic cover), Carboniferous sedimentary rocks, and major late Paleozoic faults. Compiled from Weeks (1954), Bell and Goranson (1938*a*, 1938*b*), Keppie (1979), and our mapping. BPF is the Big Pond fault system. Note the strong correlation between basement outcrop areas and elevated topography. Rectangle shows the location of Fig. 3. Circled numbers are localities referred to in text.

were active during early Carboniferous deposition, controlling the distribution of facies. But Webb studied none of these faults in detail, and some subsequent reports on the early Carboniferous in the area (e.g., Kelley 1967; Geldsetzer 1977) have made no mention of the strike-slip hypothesis. The first objective of our study was to test the hypothesis that southern Cape Breton Island was a wrench tectonic zone during early Carboniferous times.

Until very recently, a number of workers interpreted paleomagnetic data to show that the northern Appalachians were the site of a major (2000 km) *sinistral* transcurrent fault during Carboniferous times (e.g., Kent and Opdyke 1978; Van der Voo *et al.* 1979; Van der Voo 1983). This hypothesis influenced the thinking of a number of geologists (e.g., McMaster *et al.* 1980; Fralick and Schenk 1981, p. 95; Mosher 1983) who, accordingly, interpreted various Carboniferous strike-slip faults and (or) related sedimentary basins as sinistral (rather than dextral) features. New paleomagnetic findings have shown the Kent and Opdyke (1978) hypothesis to be erroneous (Irving and Strong 1984; Kent and Opdyke 1985), as Ludman (1981), Bradley (1982, 1984), and Bradley and Rowley (1983) had already argued on geologic grounds. The second objective of our study was to test the Kent and Opdyke (1978) model for Carboniferous sinistral strike slip in the northern Appalachians. The results reported here show that at least one northeast-trending strike-slip fault in Cape Breton Island was undergoing *dextral* displacement during early Carboniferous times, confirming Webb's (1969) interpretation of the dextral wrench tectonic framework and casting further doubt on the sinistral model.

Figure 2 shows the general distribution of pre-Carboniferous basement, Carboniferous sedimentary rocks, and major faults in the southeastern Brad d'Or Lake region of Cape Breton Island. High-angle faults are known or are interpreted to be the underlying cause of structural relief between topographically high Precambrian basement massifs (Boisdale Hills, Coxheath Hills, and East Bay Hills massifs: note 500 ft contour) and low-lying Carboniferous sedimentary basins (note shoreline of Bras d'Or Lake at sea level). Proximal Carboniferous sediments onlap the basement highlands in several places.

The Big Pond fault system (Fig. 2) can be traced from Sydney Basin, across the East Bay Hills, to the waters of East Bay. At a right step and bifurcation in the fault zone, near the settlement of Big Pond (Fig. 3), is a small (about 5 km²) outlier of Carboniferous conglomerates, sandstones, and minor limestones. Previous mapping in the area by Weeks (1954) revealed the distribution of basement and sedimentary cover and established a Windsorian (Visean) age for the latter, but his mapping implied, erroneously, that these sediments simply bury a preexisting valley. Our 1 : 10 000 mapping in 1982 (Fig. 3) revealed instead that the outlier is largely bounded by faults toward which the conglomerates coarsen. We have interpreted the basin as being a pull-apart one, which subsided as a consequence of oblique dextral slip on the master faults

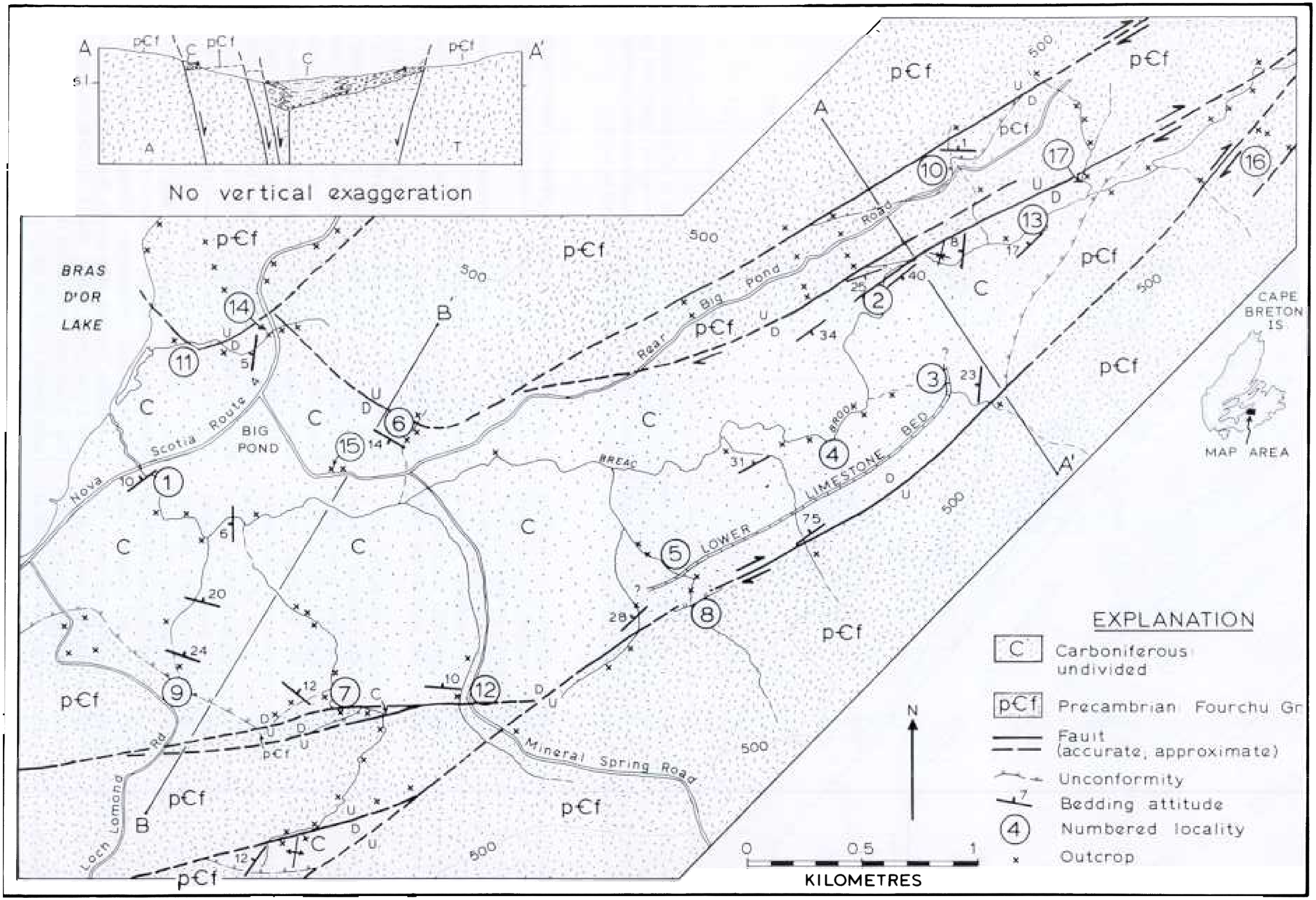

FIG. 3. Geologic map (original scale 1 : 10 000) and cross section of Big Pond Basin, Cape Breton Island. Dotted line is 500 ft (152 m) contour. "T" and "A" in cross section mean toward and away.

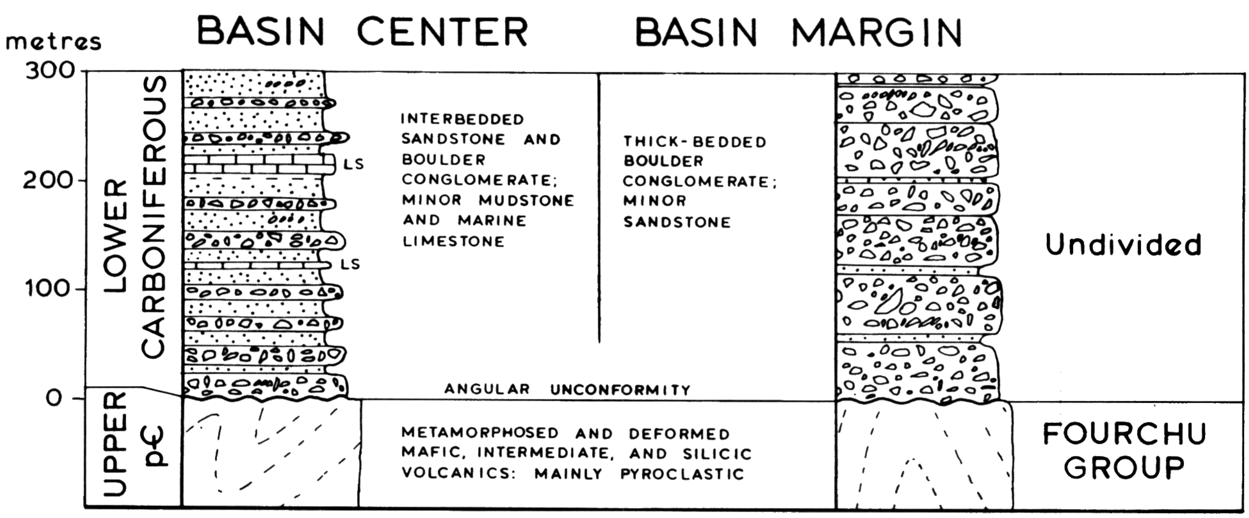

FIG. 4. Generalized Carboniferous stratigraphy of Big Pond Basin, showing interpreted lateral gradation from proximal alluvial fan to distal alluvial fan and marine facies.

(Bradley and Bradley 1983), and here present field data to support that interpretation. The name Big Pond Basin is used below to refer to both the present structural basin and to the original sedimentary basin, which we believe to have been similar in geometry.

Much of southeastern Cape Breton Island is underlain by volcanic basement of late Proterozoic age. These rocks, assigned to the Fourchu Group (Weeks 1954), underwent penetrative deformation and low-grade metamorphism in the late Proterozoic. In the Big Pond area, all basement rocks were assigned by Weeks (1954) to the Fourchu Group, and no attempt was made in the present study to further subdivide the basement complex. A variety of altered and metamorphosed volcanic lithologies is present. Most abundant are grey to green mafic to intermediate rocks, typically with altered phenocrysts of plagioclase and abundant chlorite; less common rock types include felsic porphyry with conspicuous phenocrysts of alkali feldspar, and felsic and intermediate metatuffs.

Undivided Carboniferous sedimentary rocks

General statement

The clastic fill of Big Pond Basin consists almost exclusively of red, alluvial fan facies, plus minor limestones, at least some of which are marine. Based on limited fossil evidence and inferred lateral facies relations, we concur with Weeks (1954) in assigning the entire section to the lower Carboniferous. The total thickness is not precisely known, but is estimated at 300 m. The general stratigraphy of the basin is shown in Fig. 4, and age and correlation are discussed following lithologic descriptions.

Lithology

Most of the Carboniferous sedimentary rocks in the study are are red, polymict boulder conglomerates (Fig. 5). Along the basin margins, this facies is virtually ubiquitous; in the center of the basin, it is interbedded with sandstones and rarer mudstones and limestones. Most of the conglomerate is matrix supported. The coarse fraction typically consists of a mix of boulders, cobbles, and pebbles, ranging from angular to subrounded. Of hundreds examined, all clasts were recognizable as belonging to the Fourchu Group. The maximum clast size markedly increases toward the basin margins to approximately 1 m in apparent long axis (Fig. 6). A red to brownish red colour is imparted by hematite coatings on grains; rarely, reduced horizons a few tens of centimetres thick are greyish green. Beds of the matrix-supported conglomerate typically range from 1 to 5 m thick; bedding is generally poorly defined, and the conglomerate is for the most part structureless. Lobate structures, resembling those illustrated by Rust (1981) from Carboniferous alluvial fan deposits in Quebec, were noted at locality 1 (Fig. 3). The matrix-supported conglomerates are interpreted as being debris flows deposited on alluvial fans shed from basement uplands that surrounded the basin. As will be discussed later, we believe that these fans were built along active fault scarps.

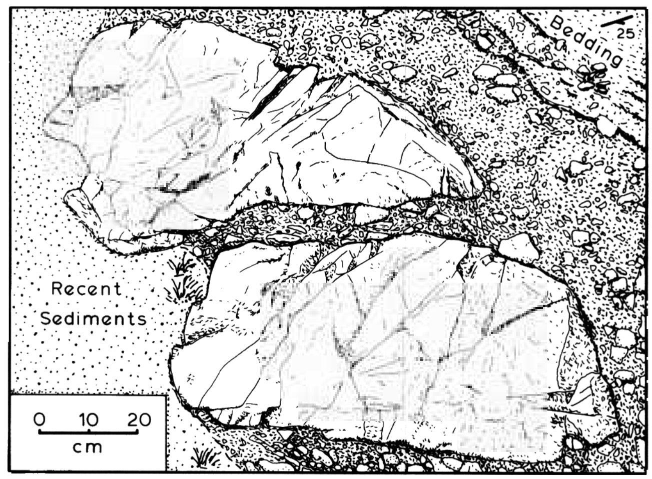

FIG. 5. Outcrop of matrix-supported boulder conglomerate containing clasts to 1 m (long axis), interpreted as being a proximal debris-flow deposit. Sketch from a photograph at locality 12, about 20 m from the present southern basin margin.

Clast-supported cobble and boulder conglomerate is less abundant; where present, it is gradational with matrix-supported conglomerate. Flat clasts are generally imbricated; this feature is the only directional indicator in the basin that is

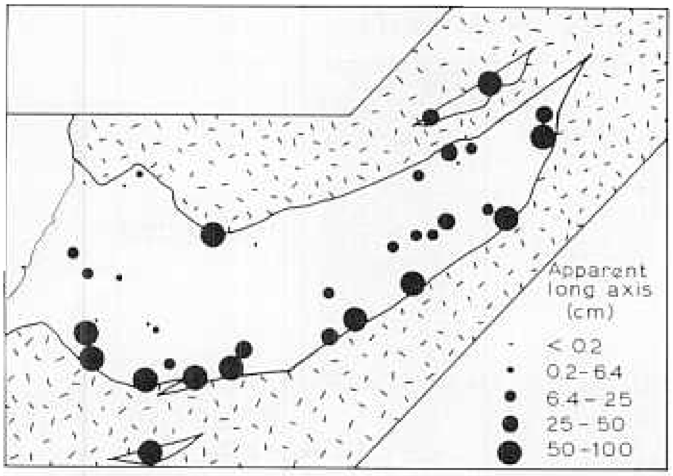

FIG. 6. Maximum clast size (apparent long axis) in Carboniferous sedimentary rocks, Big Pond Basin. Metre-sized clasts immediately adjacent to present basin margins and a decrease in size away from the basin margin faults suggest syndepositional faulting.

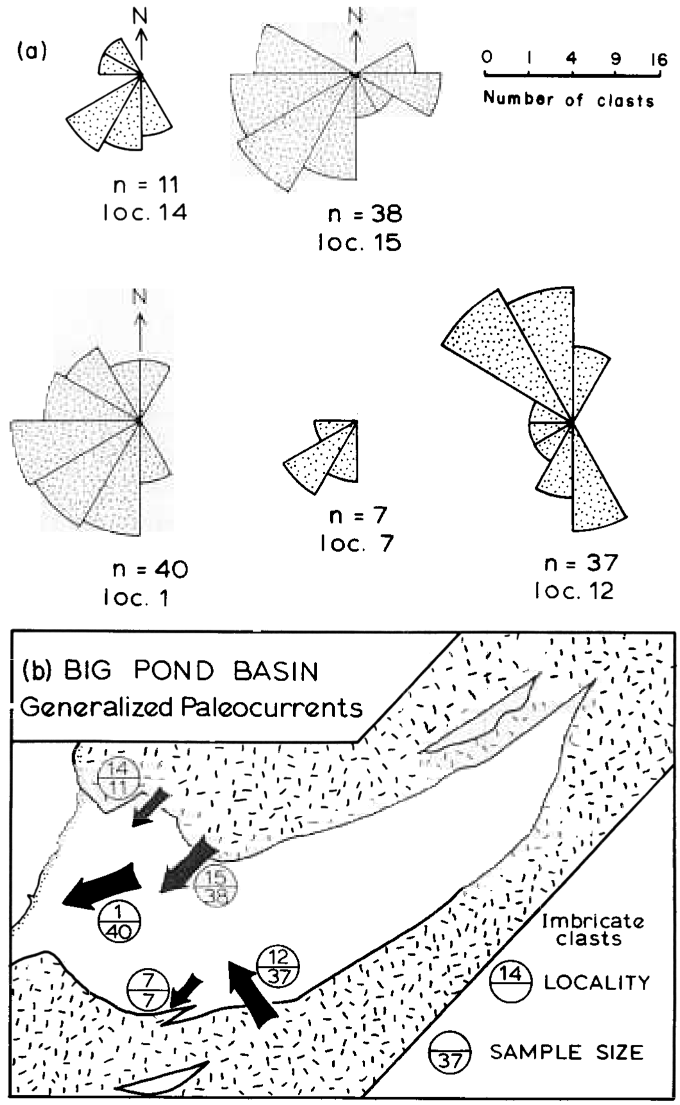

FIG. 7. (*a*) Rose diagrams showing the tilt-corrected up-dip directions of $A-B$ planes of tabular clasts in Carboniferous conglomerate. (*b*) Generalized paleocurrent directions inferred from vector means of data in (*a*), showing paleoflow into the basin from the northern and southern margins and westerly paleoflow along the basin axis. Bimodal distribution at locality 12 is a result of the presence of upstream and downstream clast dips within individual beds. Size of arrows is proportional to number of observations.

abundant enough for meaningful paleocurrent analysis. Clast imbrications indicate flow into the basin at its northern and southern margins and westward along the basin axis (Fig. 7). These rocks are interpreted as being lag deposits of ephemeral stream channels, developed locally on fans dominated by debris flows.

Thin-bedded, coarse-grained sandstones are interbedded with boulder conglomerate and mudstone and are most abundant in the area of poor outcrop in the center of the basin (Fig. 3). The sandstones, which range from red to greyish green, are of metavolcanic provenance. Pebbles and cobbles to approximately 10 cm commonly occur in some sand beds; where the tops of such beds are exposed, these oversized clasts dip in the inferred up-current direction. Bed thicknesses range from a few tens of centimetres to approximately 1 m. Sedimentary structures are notably scarce; planar cross-stratification and solitary graded beds are rarely present. These rocks are interpreted as being sheetflood deposits.

A few beds of red and grey sandy siltstones, siltstones, and claystones are interbedded with the other lithologies. These fine-grained rocks are generally massive and lack sedimentary structures. They outcrop only sparingly and were not studied in detail.

Limestone constitutes a rare (only five outcrops), but biostratigraphically important, lithology. Lithologies include cryptalgal laminite and fossiliferous, silty, and sandy limestones. The maximum exposed thickness is approximately 11 m (Fig. 3, locality 2); individual beds range from 10 cm to 1 m thick. Two limestone units are believed to be present: a lower unit (localities 3 and 5) and an upper unit (locality 4) about one third and two thirds, respectively, of the way up the 300 m section. Contact relations between limestone and alluvial sediments are shown in Fig. 8. A minor angular discordance below the limestone at locality 5 is probably the result of onlapping a fan with a depositional dip of about 10°; alternatively, it might be interpreted as being a record of synsedimentary deformation related to motion on the basin margin faults (discussed below). The possibility that the angular discordance represents a significant hiatus is less attractive to us because limestone and boulder conglomerate are conformable elsewhere in the basin.

Age and correlation of the Carboniferous rocks

Only one biostratigraphically useful fossil locality was found in Big Pond Basin. Marine fossils indicating a Windsor Subzone B age (R. G. Moore, personal communication, 1985) from shaly limestone at locality 2 (Fig. 3) include the cephalopod *Diodoceras avonensis*. Marine fossils were also observed in limestone at localities 3 and 5, but the macrofauna of dwarf crinoid columnals is not age diagnostic. The redbeds (which constitute the vast majority of the section) are entirely barren of macrofossils, and no material suitable for palynological study was found. Therefore, the relationship at locality 3 is significant, for it demonstrates that the fanglomerate and limestone intertongue and, hence, are (at least in part) lateral facies equivalents.

Weeks (1954) assigned the entire sedimentary succession at

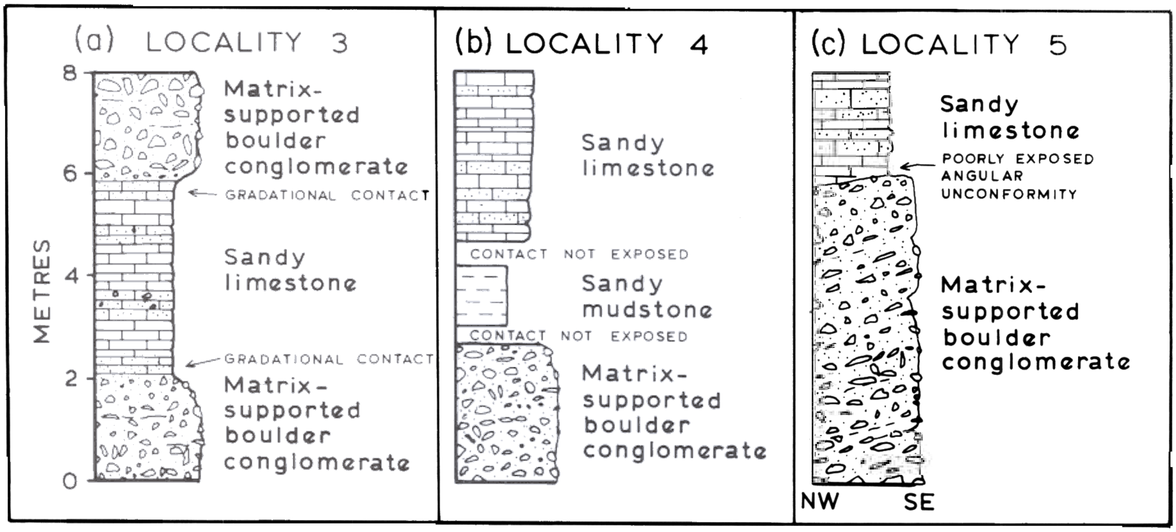

FIG. 8. Contact relations between limestone and siliciclastic facies, Carboniferous, Big Pond basin. See Fig. 3 for locations. (*a*) Limestone interbedded with matrix-supported boulder conglomerate, believed to record a marine transgression onto an alluvial fan built out from an active fault scarp at the basin margins. (*b*) Unfossiliferous limestone overlying clayey mudstone. (*c*) Limestone overlying matrix-supported conglomerate with angular unconformity. This relationship is believed to have arisen not from an episode of deformation, but from depositional dip of about 10° in the debris-flow facies. The limestones at localities 3 and 5 contain dwarf crinoid columnals and so are interpreted as marine.

Big Pond to the Windsor Group. Although he did not distinguish two units on his map, Weeks (in the accompanying report) assigned the boulder conglomerates to the Grantmire Formation and the overlying limestones, shales, sandstones, and conglomerates to the undifferentiated Windsor Group. Owing to poor outcrop and the presence of shallow dips and much conglomerate (approximately 50%) in the central part of the basin, we also found it impossible to accurately map these two units and, hence, only show the distribution of Carboniferous and Precambrian rocks in Fig. 3. In the eastern part of the basin (Fig. 3), limestone forms a marker along which the section can be broken into lower (and mainly proximal) and upper (and mainly distal) divisions. Unfortunately, this marker does not outcrop at the expected horizon elsewhere in the basin, presumably owing to facies change. On cross section A–A′ (Fig. 3), we schematically show the distribution of proximal and distal facies.

Stratigraphic nomenclature in areas of numerous small basins characterized by rapid lateral facies variations is subject to a variety of difficulties (Miall 1983), and southern Cape Breton Island is no exception. The name Grantmire was first applied in nearby Sydney Basin to a basal deposit of poorly sorted, matrix-supported boulder conglomerate, which is overlain by marine limestone or sandstone of "early Windsor" age (Bell 1938). Weeks (1954) extended the usefulness of the term Grantmire by elevating it to formation rank and applying it throughout southern Cape Breton Island, including the Big Pond area, to all basal conglomerates of the Windsor Group, regardless of age. Unlike Bell, Weeks clearly regarded the Grantmire as a time-transgressive lithologic unit. More recently, Giles (1983) reassigned Bell's (1938) original Grantmire conglomerates in Sydney Basin to the Horton Group, according to his earlier recommendations for Horton–Windsor nomenclature (Giles 1981). Unfortunately, the type Horton Group is older than the type Windsor Group, and rightly or wrongly these terms carry that implication when used elsewhere in Nova Scotia; this is *not* what we wish to imply for the conglomerates at Big Pond. We regard the conglomerates as partly, if not wholly, Visean in age, coeval with the marine Windsor Group. Accordingly, in this paper, we have sidestepped nomenclature problems by not assigning the Carboniferous strata to any formal lithologic units.

Structure

Big Pond fault system

The Big Pond fault system is a group of northeast-trending faults and subsidiary splays that crosses the East Bay Hills massif, as shown in Fig. 2. It is responsible for a pronounced linear topographic depression along the headwaters of Sydney River and Breac Brook in the remote region northeast of the study area. Big Pond Basin is located at a right step and bifurcation in the fault system around the settlement of Big Pond. Both the northern and southern margins of the basin are marked by fault zones that end at the inferred East Bay fault beneath Bras d'Or Lake (Fig. 2). Another splay is interpreted as following a topographic lineament from the southern end of Big Pond Basin to Irish Cove (Fig. 2, locality 22), where it presumably joins the submerged East Bay fault. Several lines of evidence, discussed below, together indicate dominantly dextral displacement on the northeast-striking segments and dominantly normal displacement on the east- and southeast-striking segments along the basin margins in the western part of Fig. 3. The magnitude of strike-slip displacement could not be determined but is probably less than a kilometre.

No exposures of the fault were found in the northeastern corner of the study area (Fig. 3), where the fault juxtaposes basement with basement. However, minor subvertical slickensides in the general vicinity (e.g., locality 16) strike northeasterly, parallel with the topographic lineament associated with the main fault. Slickenlines with gentle plunges indicate dominantly strike-slip motion, and fibre stepping directions indicate dextral sense (Fig. 9*a*).

Contact relations along both the northwestern and south-

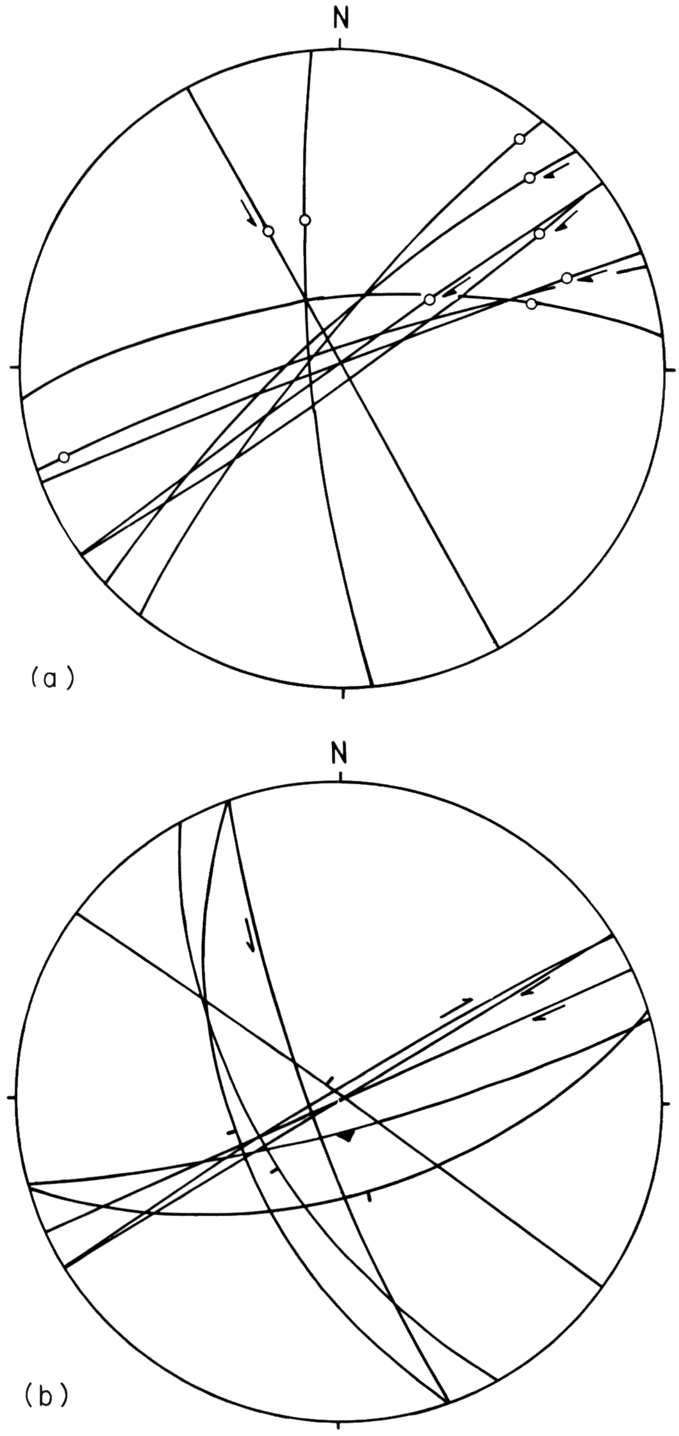

FIG. 9. Lower-hemisphere stereographic projections. (*a*) Steeply dipping slickensides (great circles) and associated gently plunging slickenlines (open circles) cutting basement rocks near the main Big Pond Fault (Fig. 3, locality 16). Faults parallel with the main strand are dextral. (*b*) Minor faults (great circles, tick marks on downthrown side where appropriate) within Big Pond Basin. Three dextral faults strike northeast, parallel with the Big Pond fault system.

eastern basin margins vary along strike. Most commonly, as at localities 6 and 7, the contact between Precambrian basement and Carboniferous sedimentary rocks is a high-angle fault, dipping steeply into the basin, with an obvious component of down-to-basin dip-slip displacement. At locality 8, a steeply

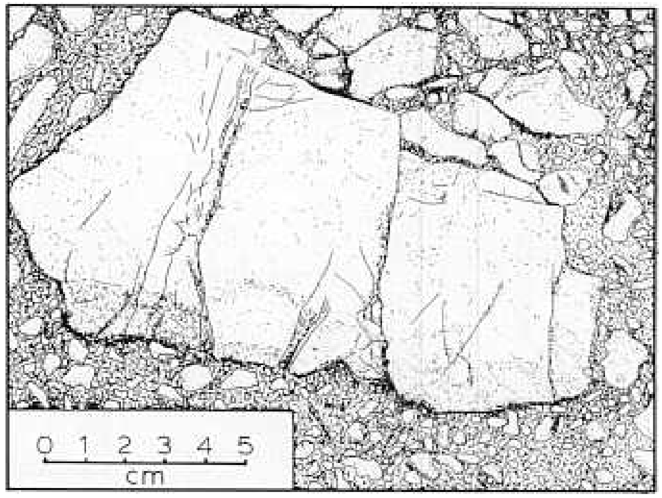

FIG. 10. Sketch from a photograph of dextral fractures in a boulder at locality 13, near the northern basin margin fault.

dipping unconformity separates fanglomerates from metavolcanics, near which motion was taken up across a wide zone of deformation within the fanglomerate. On the other hand, at localities 9 and 10, the contact is a subhorizontal unconformity. The variation in contact relations along the margins from fault to unconformity is common where alluvial fans form along active faults (e.g., Eckis 1928; Hempton *et al.* 1983), as a consequence of the fact that the fan head typically lies on the up-thrown block.

Cobbles and boulders within a few tens of metres of the basin margin faults are commonly cut by small, brittle faults (henceforth referred to as fractures) with displacements up to a few centimetres (Fig. 10). Because the surrounding matrix deformed ductilely, individual fractures cannot normally be traced from one clast to the next. To determine the sense of motion on the basin margin faults, we studied the fracture fabric at two localities along the northeast-striking basin margins and at two localities where the basin margin fault strikes east to southeast. At each outcrop, the attitude and sense of motion across 30 or more fractures were measured. Because of difficulties in matching displaced points across fractures in subrounded clasts, we were unable to measure exact slip directions. Instead, shear fractures were place in one of the following categories: dextral, down-to-basin, sinistral, and up-to-basin, and the four corresponding oblique-slip cases (dextral/down-to-basin, sinistral/down-to-basin, dextral/up-to-basin, and sinistral/up-to-basin). Dilatant cracks were placed in a ninth category. Most fractures at the four localities studied have subvertical dips, and at all localities, fractures with dextral, sinistral, and dip-slip components are present (Fig. 11).

Along the southern basin margin (locality 8), Grantmire conglomerate overlies basement along a steeply dipping unconformity, but fractured clasts occur as far as 50 m into the basin from the contact. Hence, displacement between basement and basin fill was taken up across a wide zone rather than a discrete fault. A component of down-to-basin dip slip is self-evident from the juxtaposition of Carboniferous with Precambrian rocks. However, analysis of the sense of motion on fracture surfaces reveals a large percentage with strike-slip and oblique-slip displacement (Fig. 11*a*). A conjugate set of subvertical east-striking (dextral) and northwest-striking (sinistral)

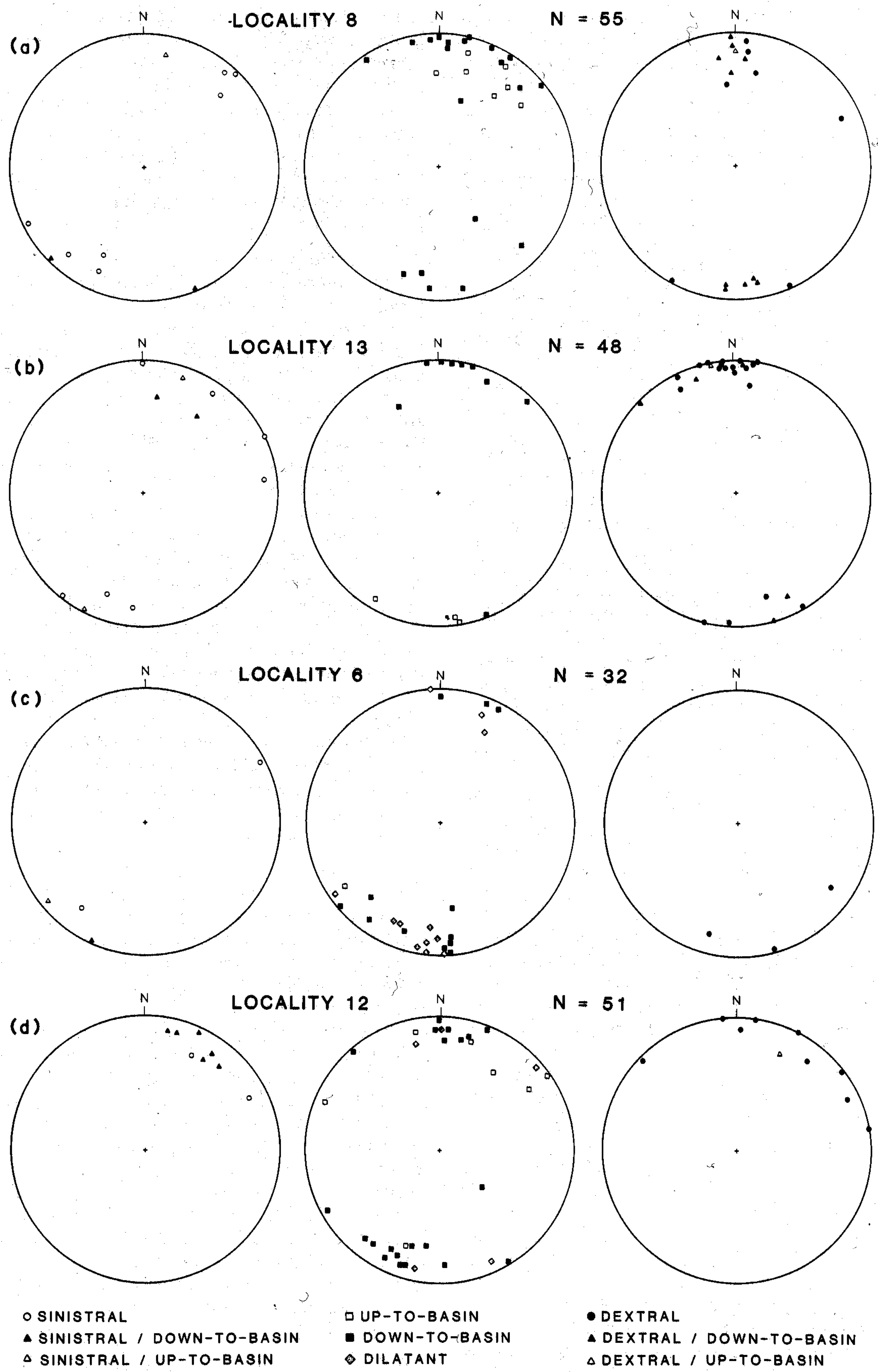

Fig. 11. Equal-area projections of poles to fractures in conglomerate clasts at four locations along the faulted margins of Big Pond Basin.

surfaces is readily apparent. The dextral fractures make a small, clockwise angle with the main fault and are best interpreted as Riedel (R) shears; the orientation of the sinistral fractures with respect to the main fault implies that they are anti-Riedel (R′) shears (e.g., Hancock 1985). Steeply dipping fractures with down-to-basin dip-slip displacement are also common. Some dip toward the basin (i.e., they are normal faults), and some dip away from the basin (i.e., they are reverse faults). Fractures from this locality together indicate that motion on the adjacent, buried master fault was an oblique combination of dextral strike slip and down-to-basin dip slip.

A similar fracture fabric was observed at locality 13 along the northern basin margin (Fig. 11*b*). The adjacent master fault strikes about 065°. As at the southern basin margin, the fractures have subvertical dips, and east-striking dextral fractures (R shears) are most abundant. A less common set strikes northwest and has sinistral offsets (R′ shears). Down-to-basin fractures are also common and should be expected in light of the obvious dip-slip component. Fractures from this locality together indicate that motion on the adjacent master fault was an oblique dextral strike slip and down-to-basin dip slip.

Locality 6 is along the northern basin margin, where the master fault strikes about 120°. Evidence already presented for dextral strike slip on the northeast-striking basin margin faults implies a component of extension on this segment, and the presence of a set of subvertical dialatant fractures with an average strike of about 100° (Fig. 11*c*) confirms that north–south extension did occur here. Down-to-basin dip-slip fractures with dips both into and away from the basin are also abundant. Rare fractures with strike-slip offsets form a weakly developed conjugate set with orientations similar to those at localities 8 and 13. Although the adjacent basin margin fault is not exposed and its dip direction is unknown, fractures from locality 6 imply that it is a normal fault.

Locality 12 is along the southern basin margin where the master fault strikes about 090°. As at locality 6, dextral strike slip on the northeast-striking basin margin faults implies a component of extension on this segment. Subvertical dilatant fractures with an average strike of about 090° (Fig. 11*d*) indicate north–south extension; however, this class of fracture is less abundant than at locality 6. Down-to-basin dip-slip fractures with dips both into and away from the basin are dominant. Unlike at the other localities, fractures with strike-slip offsets do not form a well-defined conjugate set. Although the adjacent basin margin fault is not exposed and its dip direction is unknown, the fractured clasts imply that it is a normal fault.

Similarly deformed conglomerates have been described in a variety of shallow-level tectonic settings (e.g., Ramsay 1964; Eisbacher 1969; Tyler 1975). Eisbacher deduced the sense of motion on the Cobequid Fault (a strand of the Minas fault system; Fig. 1) from principal stress directions that he inferred from fractures in individual clasts. For each clast with multiple, intersecting fractures, Eisbacher took the line of intersection of fractures to be σ_2; the line normal to this in the plane that bisects the obtuse dihedral angle between intersecting fractures as σ_3; and σ_1 normal to the other two. Eisbacher's method has several shortcomings: (1) it does not take into account the sense of displacement across fractures; (2) the stereographic construction is slow; (3) although large samples of inferred principal stress directions can be represented on equal-area projections, the raw data (i.e., the poles to fracture surfaces in individual clasts) cannot be conveniently represented; and (4) it assumes a simplistic relationship between stress and strain and ignores clast anisotropy. Nonetheless, the principal stress directions determined by Eisbacher are qualitatively consistent with other outcrop evidence for right-lateral motion on the Cobequid Fault.

We applied Eisbacher's method to 22 clasts at locality 13, where evidence already cited led us to believe that the northeast-striking basin margin fault is dextral with a component of down-to-basin dip slip. Results of Eisbacher's method also suggest dextral strike slip: σ_1 is horizontal and trends about 095°, σ_2 is vertical, and σ_3 is horizontal and trends about 005°.

Structure within the basin

The sedimentary fill of Big Pond Basin is deformed into a broad syncline, the axial trace of which corresponds to the axis of the basin. The axial trace parallels the basin margins, so that it swings from a southeasterly to a northeastly trend along strike (Fig. 3). Bedding typically steepens to as much as 80° at the marginal faults, whereas gentle dips, generally less than 30°, characterize the basin center. Two minor folds near the basin margin faults are superimposed on this broader structure: these have orientations consistent with dextral motion, if the folds and master faults are genetically related. A north-trending minor fold, located between localities 1 and 13, is truncated by the northern basin margin fault. A second minor fold (100–200 m wavelength) with a north-trending axis is truncated by the bounding fault of the small Carboniferous outlier in the southwestern corner of Fig. 3; this fault can be traced to the northeast, where it marks the southeastern margin of the basin. Folds similar to these have been described along the strike-slip faulted margins of the Carboniferous Deer Lake and Bay St. George in Newfoundland (Hyde 1979, 1982; Knight 1982).

Several minor faults outcrop within the basin (Fig. 9*b*). A strike-slip sense of motion was determined from offset markers on four of these: three are dextral faults that strike parallel with the master faults; one sinistral fault with a northwest strike completes a conjugate pattern.

Timing of fault motion

The timing of fault motion is critical to our tectonic interpretation. Some displacement clearly postdated some sedimentation, because Carboniferous strata are cut by faults at the basin margins. However, the increase in clast size toward the basin margin suggests to us that the border faults were already active during sedimentation.

The early quadrangle maps of Bell and Goranson (1938*b*) and Weeks (1954) showed that the lineament that we now recognize as the trace of the Big Pond Fault is overlapped along the southwestern margin of Sydney Basin by the Windsor Group (Fig. 2, locality 20). This raises a possible problem with our interpretation: if the Big Pond Fault was undergoing dextral motion during Visean times, the oldest overlapping strata in the relevant part of the Sydney Basin must be younger than Big Pond Basin fill. On the other hand, a more recent map by Boehner (1985) is entirely consistent with our interpretation: it shows that the Big Pond fault cuts rocks as young as the youngest preserved Windsor Group but does not cut overlying shales assigned to the Canso Group.

Tectonic interpretation

Hypothesis 1 (preferred)

Results of this study suggest that Big Pond Basin formed as a pull-apart basin (Mann *et al.* 1983) between active faults dur-

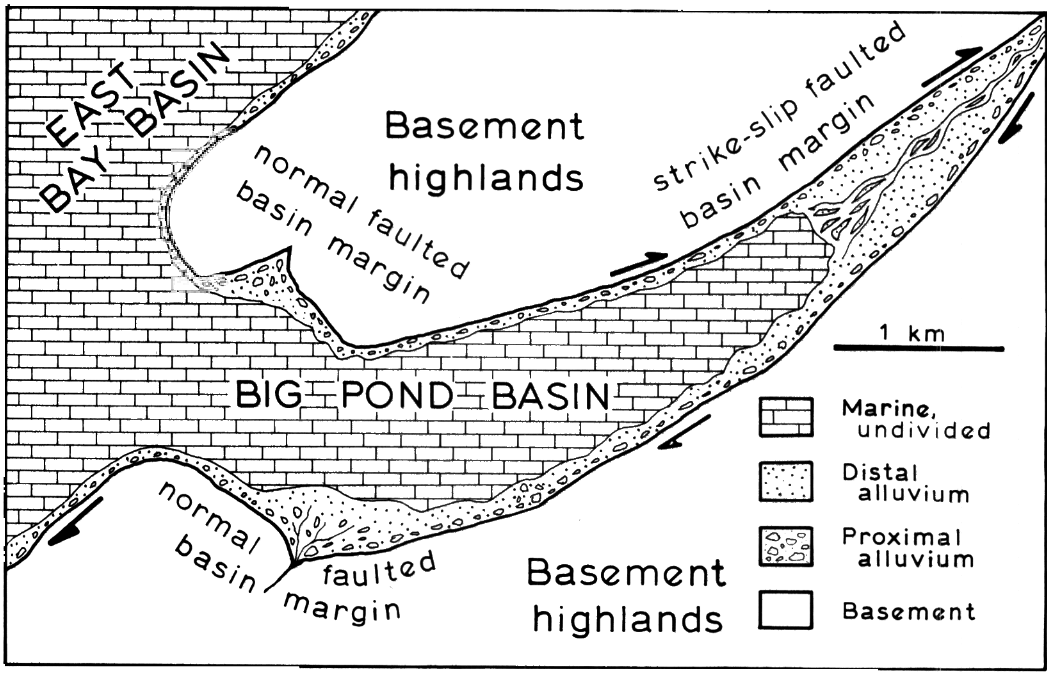

FIG. 12. Paleogeographic map of the Big Pond strike-slip basin at maximum Windsor transgression. The basin is visualized as a drowned valley that at lower stands of sea level was occupied by a fluvial system that flowed toward East Bay Basin to the west.

ing Visean times. The Carboniferous conglomerates, sandstones, shales, and limestones are interpreted as being lateral facies equivalents that were deposited in a basin not much larger than the present Carboniferous outcrop area. Based on both the overall geometry of the basin and structures within it, we view the subsidence as being the result of extension produced by simultaneous dextral strike slip on the Big Pond Fault and that part of the East Bay Fault southwest of Big Pond (Fig. 12). The broad synclinal structure of the basin is likely the result of some combination of (1) drag associated with the dip-slip component of motion on the basin margin faults, (2) differential compaction of finer grained clastics in the center of the basin, (3) primary fanglomerate dips, and (4) late Carboniferous (or younger) regional compression, which deformed Sydney Basin to the northeast and Glengarry half graben to the southeast (e.g., Boehner and Prime 1985). The two north-trenching folds near the basin margins are likely to be the product of the same dextral motion that produced the basin and need not be attributed to a later phase of deformation. Northeast-trending faults in New Brunswick, northern Cape Breton Island, and Newfoundland were also undergoing dextral strike slip during Tournaisian and Visean times (Webb 1939, 1969; Belt 1968; Hyde 1979; Bradley 1984; Bradley and Bradley 1984). The same sense of displacement would, therefore, be likely on faults of the same orientation active during that interval in southern Cape Breton Island. The various lines of evidence cited above for dextral strike slip argue as well against sinistral strike slip. For subsidence of Big Pond Basin to have been driven by sinistral strike slip, a transpressional origin is required. However, the basin margin faults at localities 6 and 12 are extensional.

Hypothesis 2

Because the basin is a broad syncline in cross section, coarsening of the conglomerate toward its margins could be interpreted to show that the same fining-upward boulder conglomerate unit is exposed on either limb. The implication is that on a scale larger than the present Big Pond Basin, the Carboniferous section approximates a layer cake. Prime and Boehner (1984) interpreted the mainly younger Carboniferous sequence in the nearby Glengarry half graben (Fig. 2) as having been deposited in a much larger basin than is now preserved. On a more regional scale, Van de Poll (1972), Geldsetzer (1977), and Moore and Austin (1984) have argued for a single regional Windsor basin, rather than a series of small basins localized between active faults.

The following evidence argues against hypothesis 2: (1) the sedimentary fill of the Big Pond basin is composed *exclusively* of local Fourchu Group lithologies: (2) clasts up to 1 m in long axis cannot have travelled far; (3) paleocurrents flowed into the area now occupied by Carboniferous strata (Fig. 7); and (4) topographically low Windsor Group sediments bury inferred faults and onlap topographically high basement massifs at numerous places in the area of Fig. 2 (localities 19–24). At locality 23, Weeks (1954, pp. 74–75) described a particularly significant unconformable onlap of basal Windsor conglomerate over Fourchu metavolcanics. The unconformity dips to the west more steeply than bedding in the Windsor, and individual conglomerate beds grade laterally (toward the center of East Bay Basin) into limestone within a few metres of the contact. Similarly, Prime and Boehner (1984, p. 67) recognized that along the eastern side of the Glengarry half graben (locality 25), the sub-Carboniferous unconformity dips northwest more steeply than the Carboniferous strata that onlap it. Similar relations can be inferred at localities 19, 20, 21, and 24. The picture that emerges is that during Visean times, southeastern Cape Breton Island was the site of many small, interconnected basins rather than a single broad basin of layer-cake deposition that was subdivided as a result of later deformation. Prime and Boehner's (1984) interpretation of the Glengarry half graben as the remnant of a once larger basin is not necessarily at odds with our preferred hypothesis for Big

Pond Basin because the Glengarry half graben is mainly filled with upper Carboniferous strata, which are not preserved at Big Pond.

Paleogeographic synthesis

During much of its development, Big Pond Basin was entirely nonmarine and was an area of rapid sedimentation on small, coalesced alluvial fans that developed along its strike-slip and normal faulted margins (Fig. 12). Debris flows dominated the upper reaches of small fans, and ephemeral streams occasionally reworked the debris flows, winnowing away the matrix. More-distal sheetflood deposits were the dominant sediments of the basin center. Paleocurrent data reveal that paleoflow was toward the basin center and westward along its axis toward East Bay Basin. At least once, and probably twice during Visean times, marine water entered Big Pond Basin. Exposures on either side of East Bay of fanglomerate, gypsum, and Windsor subzones B and C limestone indicate that East Basy Basin was a marine depocenter of significant duration; it seems fairly certain that this was the marine connection of Big Pond Basin. Big Pond Basin may be visualized as a tributary valley to East Bay Basin, which was drowned when relative sea level rose, as it did repeatedly during Visean times (Giles 1981).

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