THE COCORP SOUTHERN APPALACHIAN TRAVERS

F. A. Cook, L. D. Brown, S. Kaufman and J. E. Oliver
Department of Geological Sciences, Cornell University

The COCORP southern Appalachian seismic reflection traverse provides evidence that the crystalline rocks at and near the surface well east of the Valley and Ridge were thrust westward above Late Precambrian and Early Paleozoic miogeoclinal strata. These data thus imply that the "thin-skinned" style of deformation is applicable to the crystalline "cores," as well as the often documented forelands, of many orogenic belts.

The traverse, which includes some 700 km (435 mi) of profile (including cross lines) from near Madisonville in the Valley and Ridge of eastern Tennessee to near Savannah in the Coastal Plain of Georgia, is the first crustal-scale seismic reflection profile in the public domain to transect an entire orogen. From west to east the major elements of this part of the Appalachians include the Valley and Ridge, Blue Ridge, Brevard zone, Inner Piedmont, Charlotte belt,Carolina slate belt, Eastern Piedmont (Kiokee belt, Augusta fault, Belair belt), and Coastal Plain (Figure 1). With the exception of a gap of about 60 km (37 mi) in the Blue Ridge, the seismic traverse is continuous across all of these belts.

Generalized interpretations were previously presented (Cook et al, 1979; 1981) and a more detailed discussion is developed in Cook et al (1982). Several of the major discoveries which resulted from these profiles are briefly noted here.

The data were recorded in two phases of field acquisition (Figure 1). The first phase, recorded in 1978 and 1979, resulted in the completion of the traverse from the Valley and Ridge to the east side of the Carolina slate belt. The second phase resulted in the extension of the profiles across the Eastern Piedmont and Coastal Plain.

Nearly 350 km (217 mi; including cross-lines) of data were acquired in the first phase of profiling which led to some important fundamental discoveries (Cook et al, 1979). Of primary significance is the observation that nearly horizontal reflections, most likely from Paleozoic sedimentary layers, could be traced at 1.5 to 2.0 secs (about 4.5 to 6 km, 13,500 to 18,000 ft) from the Valley and Ridge to beneath the Blue Ridge (Figures 2A, 3A). Furthermore, similar horizontal reflections are observed beneath the eastern Blue Ridge, Brevard zone, and Inner Piedmont (Figures 2B, 3B). In spite of the 60 km (37 mi) data gap in the Blue Ridge, the reflections on the west probably correlate with those on the east. Several independent lines of evidence also lead us to believe that the layers beneath the Brevard zone and Inner Piedmont are similarly Precambrian and/or Paleozoic metasedimentary layers. These have been described in Cook et al (1979; 1982).

Structural complexities within these buried layers are indeterminate of this time; it is possible that layer-parallel faulting has produced shortening which is not resolvable on the seismic data. Furthermore, the compositions, ages, and metamorphic grades of these layers are similarly unknown, but are clearly of major tectonic and economic significance. For example, these layers, if indeed they are of sedimentary origin, may (in places) not have been subjected to high levels of metamorphism and may thus be future targets for hydrocarbon exploration.

Presence of subhorizontal reflections beneath the Inner Piedmont southeast of the Brevard zone, coupled with the correlations observed on conductivity profiles (D. McMurdie and Y. Shoram, personal commun., 1981) provide evidence that the metasediment layering extends eastward. Although, the layers at 3.0 to 4.0 secs (about 9 to 12 km or 30,000 to 39,000 ft; Figures 2B and 3B) beneath the Inner Piedmont could be reflections from detachment surfaces, mylonites, layered intrusives, or any other layered rocks which could provide reflected energy. However, the lateral correlation of these layers with those beneath the Blue Ridge and Brevard zone strongly suggests they are stratigraphically correlative.

Near the Inner Piedmont-Charlotte belt transition, significant changes are seen in the reflection data. The nature of these changes is as yet somewhat ambiguous; two plausible interpretations are shown in Figures 4 and 5. In Figure 4 these layers are shown as layers of sedimentary origin which may be the metamorphosed basinal facies equivalents of the shelf (miogeoclinal) facies beneath the Blue Ridge and Inner Piedmont (Cook et al, 1979; 1981), or of extensive detachments. In this interpretation, subhorizontal detachments extend far to the east beneath the Coastal Plain. In Figure 5, these layers are shown as a "root zone" for the faults and nappes of the Inner Piedmont and Blue Ridge (Cook et al, 1979; Hatcher and Zietz, 1980; Cook et al, 1981; Figure 7).

The second phase traverse crosses the southwestward projection of the Augusta fault (Figure 1), which was interpreted as a Late Paleozoic thrust fault (Snoke et al, 1980), and then into the Coastal Plain. A major east-dipping band of reflections beneath the Coastal Plain appears to project to the surface position of the Augusta fault (Figure 4). This zone is therefore interpreted as reflections either from the mylonites of the Augusta fault or from the contrast between the lithologies of the Belair belt on the southeast and Kiokee belt on the northwest. As this feature can apparently be traced for some 80 to 100 km (49 to 62 mi) to the southeast to traveltimes of 4 to 5 secs (about 12 to 15 km or 39,000 to 49,000 ft), the Augusta fault is clearly a major structural boundary in the area.

An important point is that the Augusta fault and related structures of the Kiokee belt display significant west-directed compression in the Late Paleozoic (Snoke et al, 1980). The timing of the major metamorphic and deformational events in the Eastern Piedmont are then coincident with the classical Alleghanian deformation in the Valley and Ridge, strongly implying that they were related to a common stress-producing system (plate collision). The recognition of Late Paleozoic Alleghanian-Hercynian compression in the Eastern Piedmont thus precludes models which call upon in situ vertical uplift of the Piedmont and gravity-driven motion to produce the Valley and Ridge structures; it would be difficult to produce westward — directed compression east of such a Piedmont uplift.

Beneath the Coastal Plain are several reflections which appear listric into the underlying Augusta fault (Figure 3). At least one of these extends to the surface in the vicinity of a Triassic fault. In this case a dipping reflection near station 1500 on Line 5 may be a reflection from a fault on the west side of the Riddleville basin (Figures 3, 4, 5). As Cook et al (1981) suggested these listric events may be Triassic normal faults, Paleozoic thrust faults, or Paleozoic thrust faults which were reactivated as Triassic normal faults.

At later traveltimes than the Augusta fault reflection (Figures 2C, 3C) are numerous reflection events to 12 to 13 secs. Although it is not clear at this time how these may be interpreted, some possonal commun., 1981) provide evidence that the metasediment layering extends eastward. Although, the layers at 3.0 to 4.0 secs (about 9 to 12 km or 30,000 to 39,000 ft; Figures 2B and 3B) beneath the Inner Piedmont could be reflections from detachment surfaces, mylonites, layered intrusives, or any other layered rocks which could provide reflected energy. However, the lateral correlation of these layers with those beneath the Blue Ridge and Brevard zone strongly suggests they are stratigraphically correlative.

Near the Inner Piedmont-Charlotte belt transition, significant changes are seen in the reflection data. The nature of these changes is as yet somewhat ambiguous; two plausible interpretations are shown in Figures 4 and 5. In Figure 4 these layers are shown as layers of sedimentary origin which may be the metamorphosed basinal facies equivalents of the shelf (miogeoclinal) facies beneath the Blue Ridge and Inner Piedmont (Cook et al, 1979; 1981), or of extensive detachments. In this interpretation, subhorizontal detachments extend far to the east beneath the Coastal Plain. In Figure 5, these layers are shown as a "root zone" for the faults and nappes of the Inner Piedmont and Blue Ridge (Cook et al, 1979; Hatcher and Zietz, 1980; Cook et al, 1981; Figure 7).

The second phase traverse crosses the southwestward projection of the Augusta fault (Figure 1), which was interpreted as a Late Paleozoic thrust fault (Snoke et al, 1980), and then into the Coastal Plain. A major east-dipping band of reflections beneath the Coastal Plain appears to project to the surface position of the Augusta fault (Figure 4). This zone is therefore interpreted as reflections either from the mylonites of the Augusta fault or from the contrast between the lithologies of the Belair belt on the southeast and Kiokee belt on the northwest. As this feature can apparently be traced for some 80 to 100 km (49 to 62 mi) to the southeast to traveltimes of 4 to 5 secs (about 12 to 15 km or 39,000 to 49,000 ft), the Augusta fault is clearly a major structural boundary in the area.

An important point is that the Augusta fault and related structures of the Kiokee belt display significant west-directed compression in the Late Paleozoic (Snoke et al, 1980). The timing of the major metamorphic and deformational events in the Eastern Piedmont are then coincident with the classical Alleghanian deformation in the Valley and Ridge, strongly implying that they were related to a common stress-producing system (plate collision). The recognition of Late Paleozoic Alleghanian-Hercynian compression in the Eastern Piedmont thus precludes models which call upon in situ vertical uplift of the Piedmont and gravity-driven motion to produce the Valley and Ridge structures; it would be difficult to produce westward — directed compression east of such a Piedmont uplift.

Beneath the Coastal Plain are several reflections which appear listric into the underlying Augusta fault (Figure 3). At least one of these extends to the surface in the vicinity of a Triassic fault. In this case a dipping reflection near station 1500 on Line 5 may be a reflection from a fault on the west side of the Riddleville basin (Figures 3, 4, 5). As Cook et al (1981) suggested these listric events may be Triassic normal faults, Paleozoic thrust faults, or Paleozoic thrust faults which were reactivated as Triassic normal faults.

At later traveltimes than the Augusta fault reflection (Figures 2C, 3C) are numerous reflection events to 12 to 13 secs. Although it is not clear at this time how these may be interpreted, some possibilities include detachment horizons, layered metasediments, and layered intrusives.

Some 80 km or more (about 50 mi) southeast of the surface position of the Augusta fault, the reflection data change significantly. Near 4 to 6 secs (about 11 to 18 km, or 7 to 11 mi) the dominantly horizontal and eastward-dipping reflections appear to show a distinct change in orientation to more westward dips (Figure 3, Lines 5 and 8). It is not yet clear if this change represents a major tectonic transition. Based on the reflection data alone, the similarity of the west-dipping layering on Line 8 with those on Line 5 suggest they are correlative. If such is the case it would seem unlikely that this change in reflection orientation is a major suture, but rather represents structural complexity in the layering, with no crustal penetrating suture.

If the interpretation of the layers beneath the Charlotte and slate belts — as basinal facies (meta?) sediments — is correct, it suggests that many of the layers within the crust east of the slate belt may be correlative with those at midcrustal levels beneath the slate belt (Figure 4) thus suggesting that subhorizontal detachments extend far to the east. However, if the east-dipping layers beneath the Charlotte belt are a "root zone," detachments would not extend continuously in the subsurface east of the Carolina slate belt, and the many intracrustal layers observed on the second phase traverse could be interpreted in any number of ways. For example, they may be layered intrusions or layered metamorphic rocks which are unrelated to the miogeoclinal strata to the west.

Near the southeastern end of the traverse an antiformed structure (called the Statesboro anticline by Cook et al, 1982) is observed on Line 8 (Figures 2D, 3D). The crest of this feature is at about 2.3 secs (about 5.0 to 5.5 km or 16,000 to 18,000 ft) and is thus well within the limits of present drilling technology. Although the closure of this structure would certainly be attractive to exploration interest in a more traditional geologic setting, the lithologies and metamorphic grades of these layers are unknown.

CONCLUSIONS

The COCORP seismic reflection traverse in the southern Appalachians provides data which indicate that the crystalline rocks of the southern Appalachians are detached at shallow structural levels in the crust. On the west, the crystalline rocks of the Blue Ridge and Inner Piedmont overlie miogeoclinal sedimentary strata (metasediments to the east) which stratigraphically correlate with Valley and Ridge strata. On the east, complex layering in the crust may be from detachments or metasediments which were buried due to thrusting. The data thus suggest that the crystalline rocks of many orogens may be detached at shallow structural levels.

ACKNOWLEDGMENTS

The COCORP southern Appalachian data were obtained by Petty-Ray Geophysical division of Geosource, Inc., in 1978, 1979, and 1980. COCORP is funded by the National Science Foundation under grants EAR 78-23672 and EAR 78-23673.

REFERENCES

Cook, F., et al, 1979, Thin-skinned tectonics in the crystalline southern Appalachians; COCORP seismic reflection profiling of the Blue Ridge and Piedmont: Geology, v. 7, p. 563-567.

——— et al, 1981, COCORP seismic profiling of the Appalachian orogen beneath the Coastal Plain of Georgia: Geol. Soc. America Bull., v. 92, p. 738-748.

——— et al, 1982, The COCORP seismic reflection traverse across the southern Appalachians: AAPG Stud. in Geology No. 14, 61 p.

Hatcher, R., Jr., and I. Zietz, 1980, Tectonic implications of regional aeromagnetic and gravity data from the southern Appalachians, *in* D. Wones, ed., Proceedings of the IGCP Caledonides Orogen Project — the Caledonides in the U.S.A.: Virginia Polytechnic Inst. Mem. 2, p. 235-244.

Snoke, A., S. Kish, and D. Secor, Jr., 1980, Deformed Hercynian granitic rocks from the Piedmont of South Carolina: Am. Jour. Science, v. 280, p. 1018-1034.

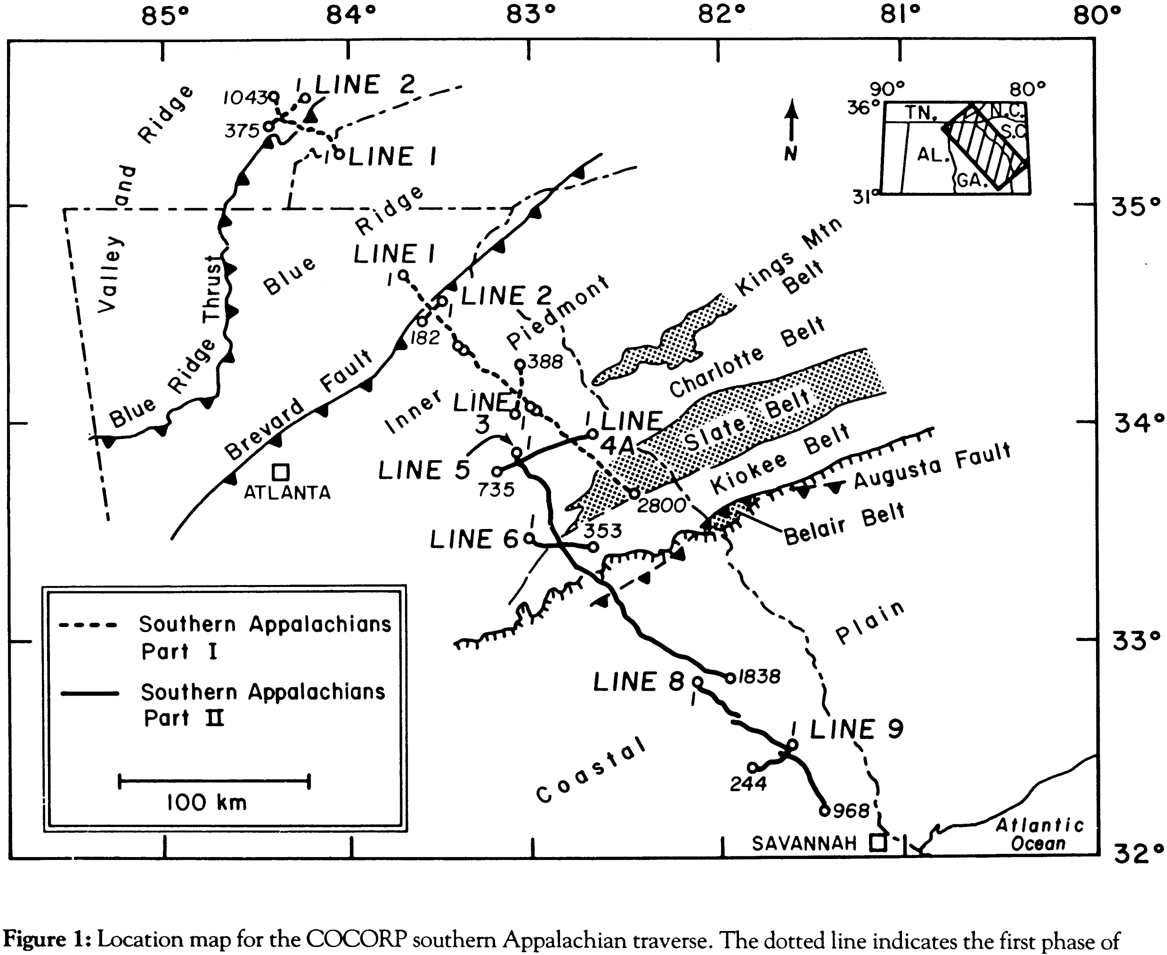


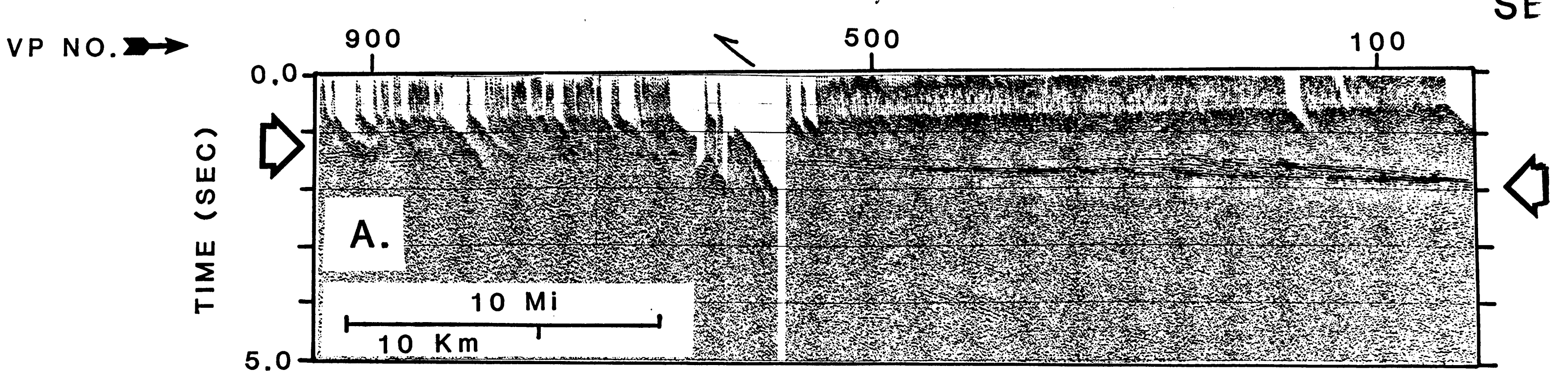
Figure 1: Location map for the COCORP southern Appalachian traverse. The dotted line indicates the first phase of profiling and the solid line indicates the second.

TITLE BLOCK

Title: Southern Appalachian Traverse
Authors: F. A. Cook, L. D. Brown, S. Kaufman and J. E. Oliver
Institution: Cornell University
Geologic Region: Southern Appalachian Traverse
Horizontal Scale: 1:560,000
Vertical Scale: 1:560,000

GEOPHYSICAL TITLE BLOCK

Energy Source: Vibroseis
Stacking Multiplicity: 24-fold, 18-fold (line 8)
No. of Channels: 96
Station Interval: Phase 1 - 67 m (220 ft)
Phase 2 - 100 m (330 ft)
Minimum Offset Distance: Phase 1 - 469 m (1,540 ft);
Phase 2 - 402 m (1,320 ft)
Maximum Offset Distance: Phase 1 - 6,906 m (22,660 ft);
Phase 2 - 9,957 m (32,667 ft)
Static Corrections: Phase 1 - datum 250 m (820 ft); velocity 4.6 km/sec (2.9 mi/sec)
Phase 2 - datum 120 m (394 ft); velocity 4.6 km/sec (2.9 mi/sec)
Deconvolution: 1,000 msec operator; design window, 0.2 to 10.0 secs; and 0.2 to 6.0 secs. Apply 0.0 to 20.0 secs
Frequency Filtering: Phase 1 - 0.0 to 1.5 secs, 16-32 hz; 1.5 to 2.5 secs, 12-32 hz; 2.5 to 20.0 secs, 8-32 hz
Frequency Filtering: Phase 2 - 0.0 to 2.0 secs, 16-40 hz; 2.0 to 5.5 secs, 16-40 hz; 5.5 to 20.0 secs, 8-40 hz
Sources of Velocities: velocity spectra, constant velocity stacks
Migration: none



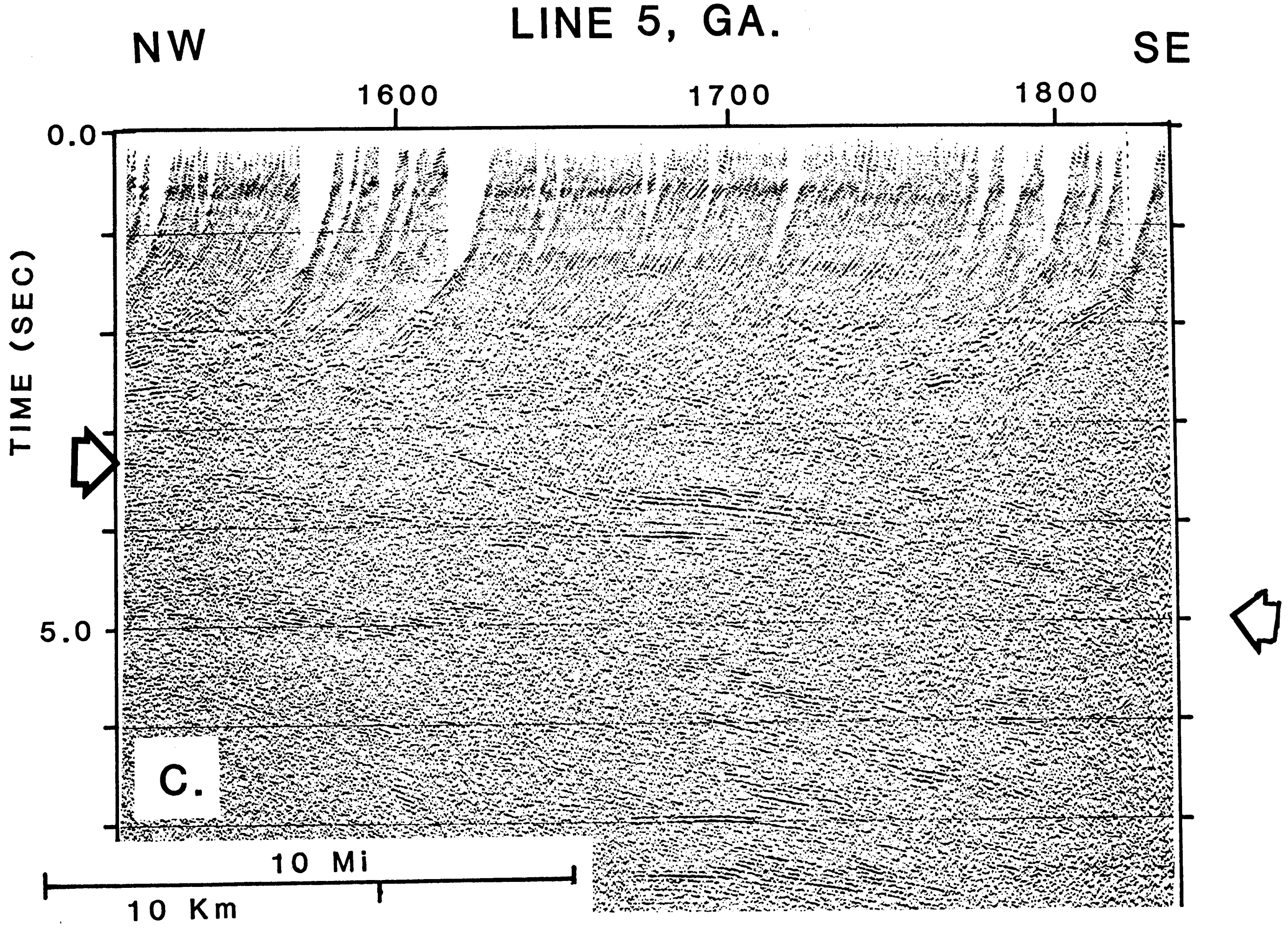


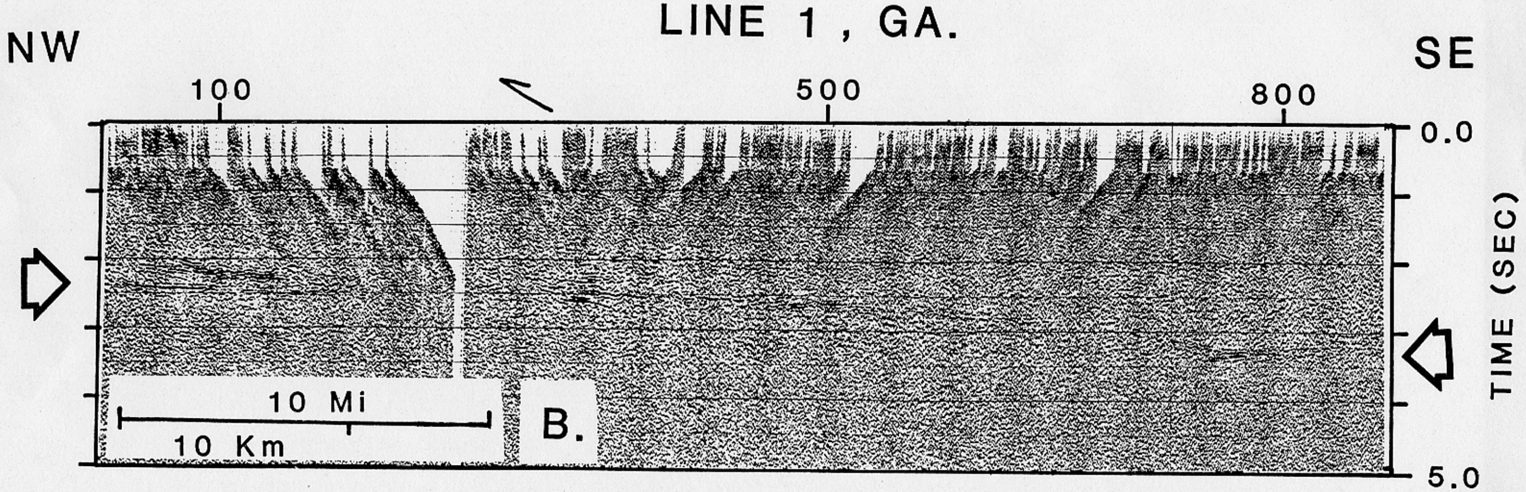
Figure 2: Seismic data from four locations along the traverse. Each is keyed by letter (A, B, C, D) to outlined areas on Figure 3.

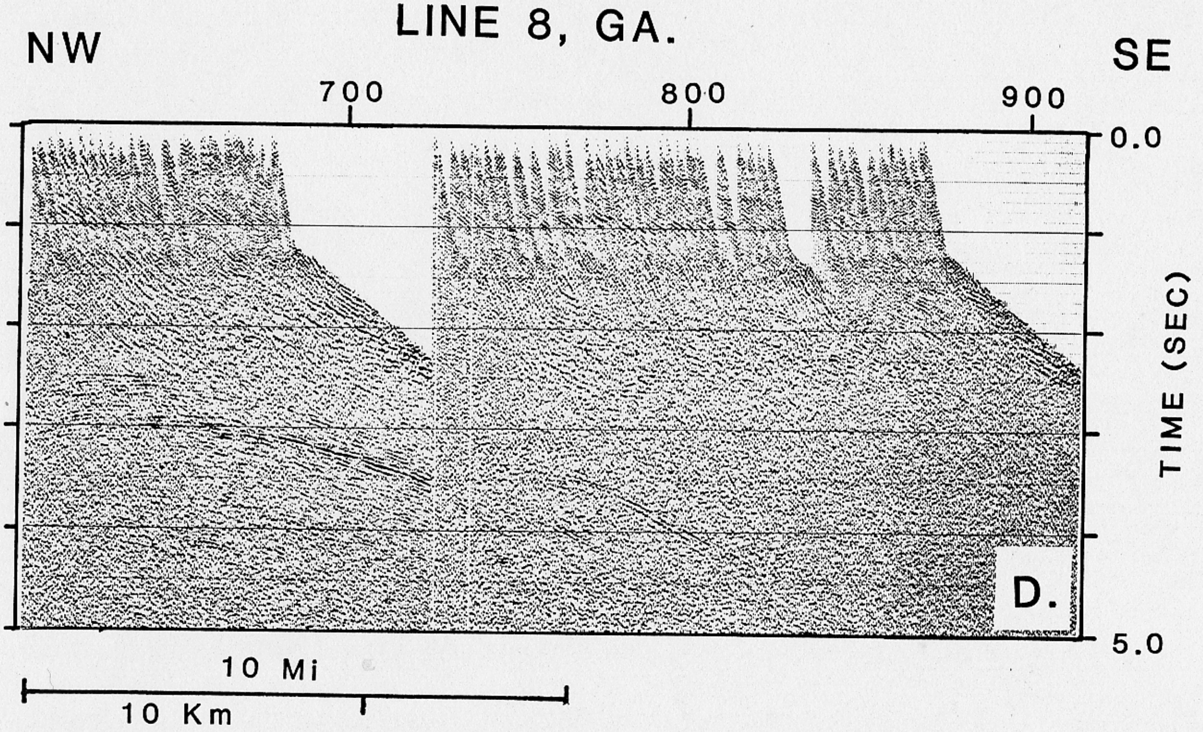
(A.) Data from the Valley and Ridge-Blue Ridge line. The open arrows denote the location of Paleozoic sediments; the thrust arrow near station 600 denotes the approximate surface position of the Great Smokey thrust.

(B.) Data from the Blue Ridge-Brevard-Inner Piedmont line. The open arrows denote layering interpreted as Precambrian to Paleozoic (meta?)sediments. The thrust arrow near station 300 denotes the approximate surface position of the Brevard thrust.

(C.) Data from Line 5, Georgia. The open arrows indicate reflections from the Augusta fault zone; the Riddleville Triassic basin is located between stations 1500 and 1800.

(D.) Data from Line 8, Georgia, which display a prominent antiformal reflection.


LINE 1 , GA.
NW
SE
100
500
800
0.0
5.0
TIME (SEC)
10 Mi
10 Km
B.


LINE 8, GA.
NW
SE
700
800
900
0.0
5.0
TIME (SEC)
D.
10 Mi
10 Km

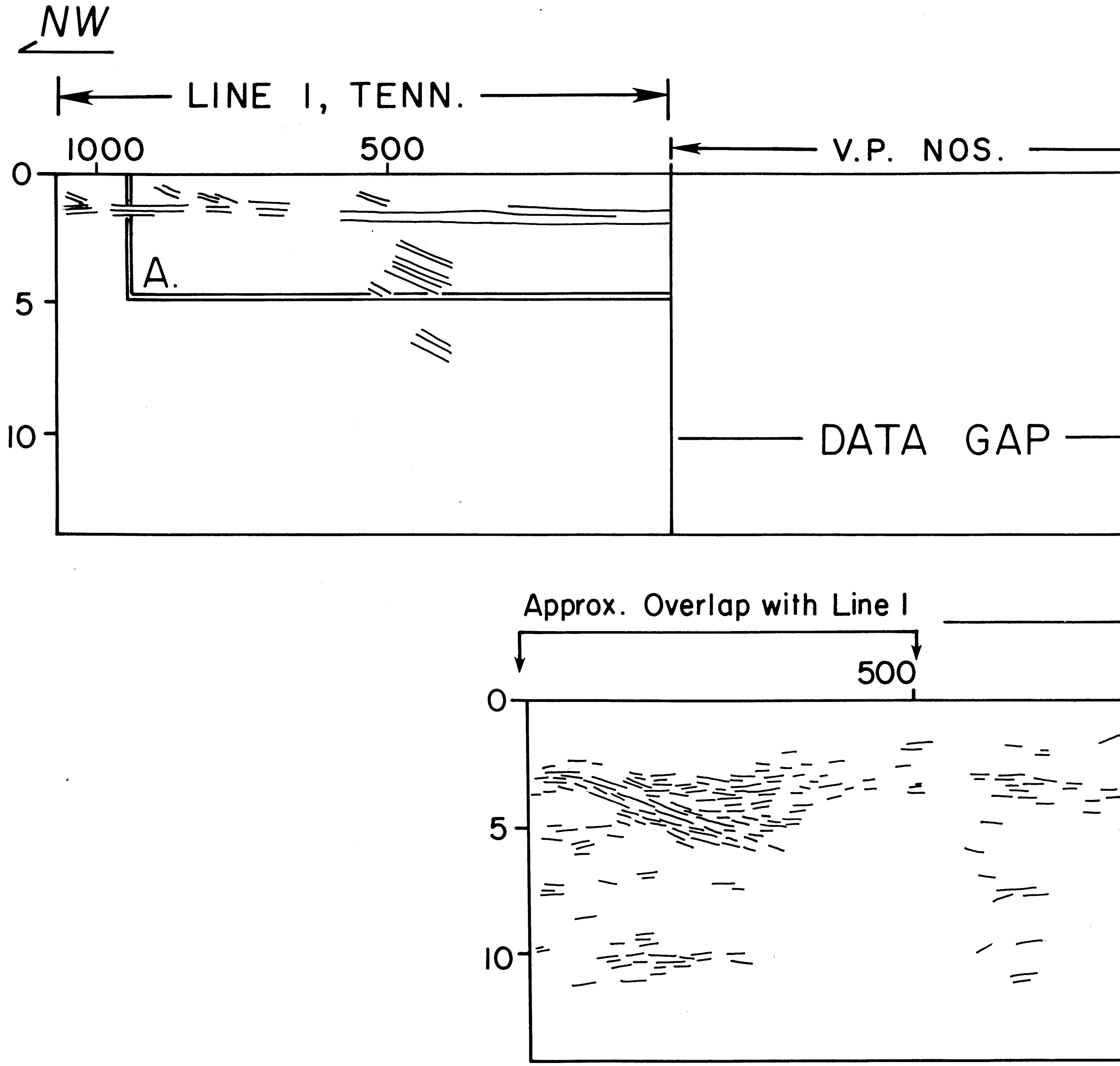
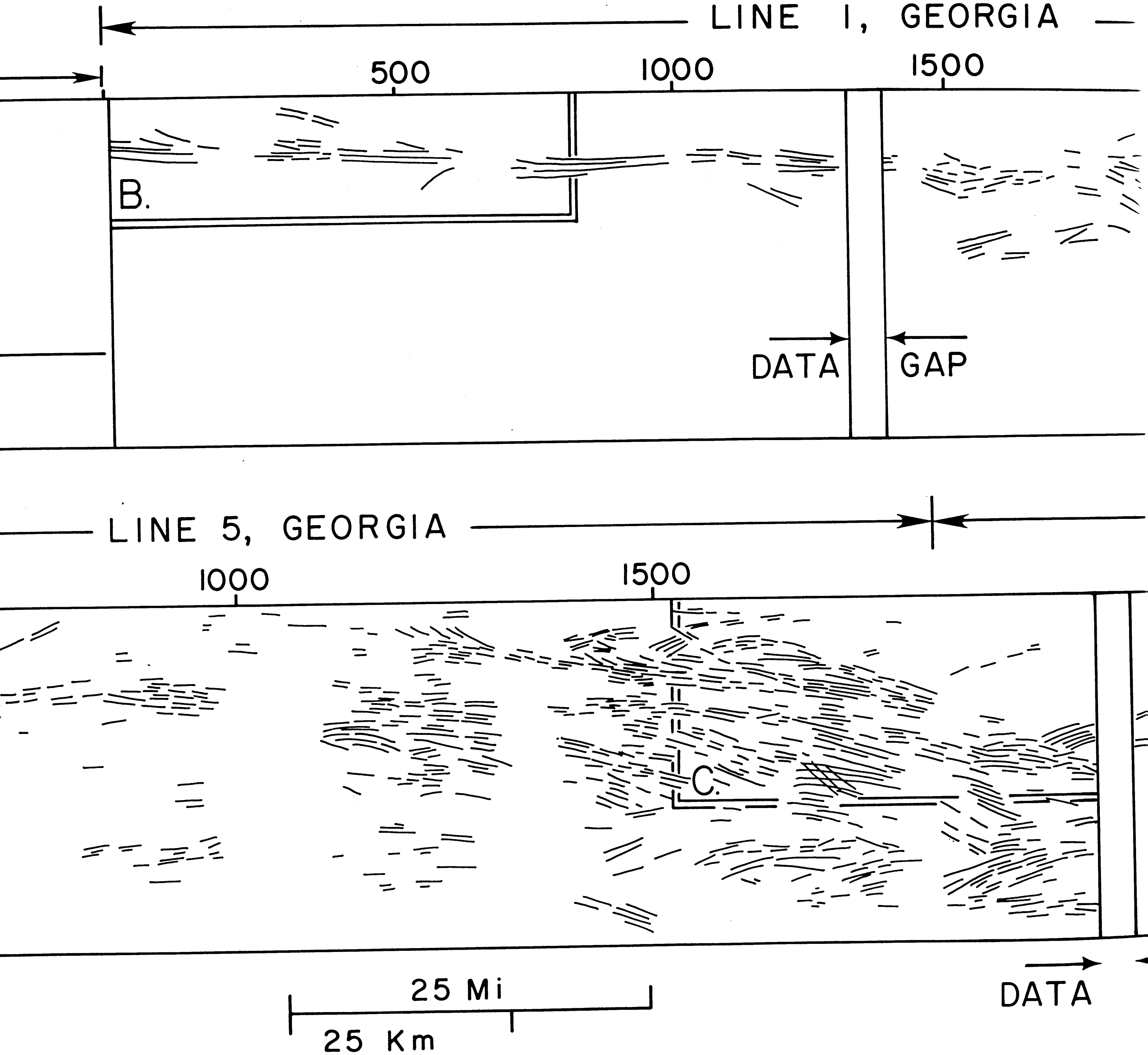


Figure 3: Line drawing of the entire southern Appalachian reflection data. Letters refer to areas enlarged in Figure 2.


LINE 1, GEORGIA
500
1000
1500
B.
DATA
GAP
LINE 5, GEORGIA
1000
1500
C.
25 Mi
25 Km
DATA

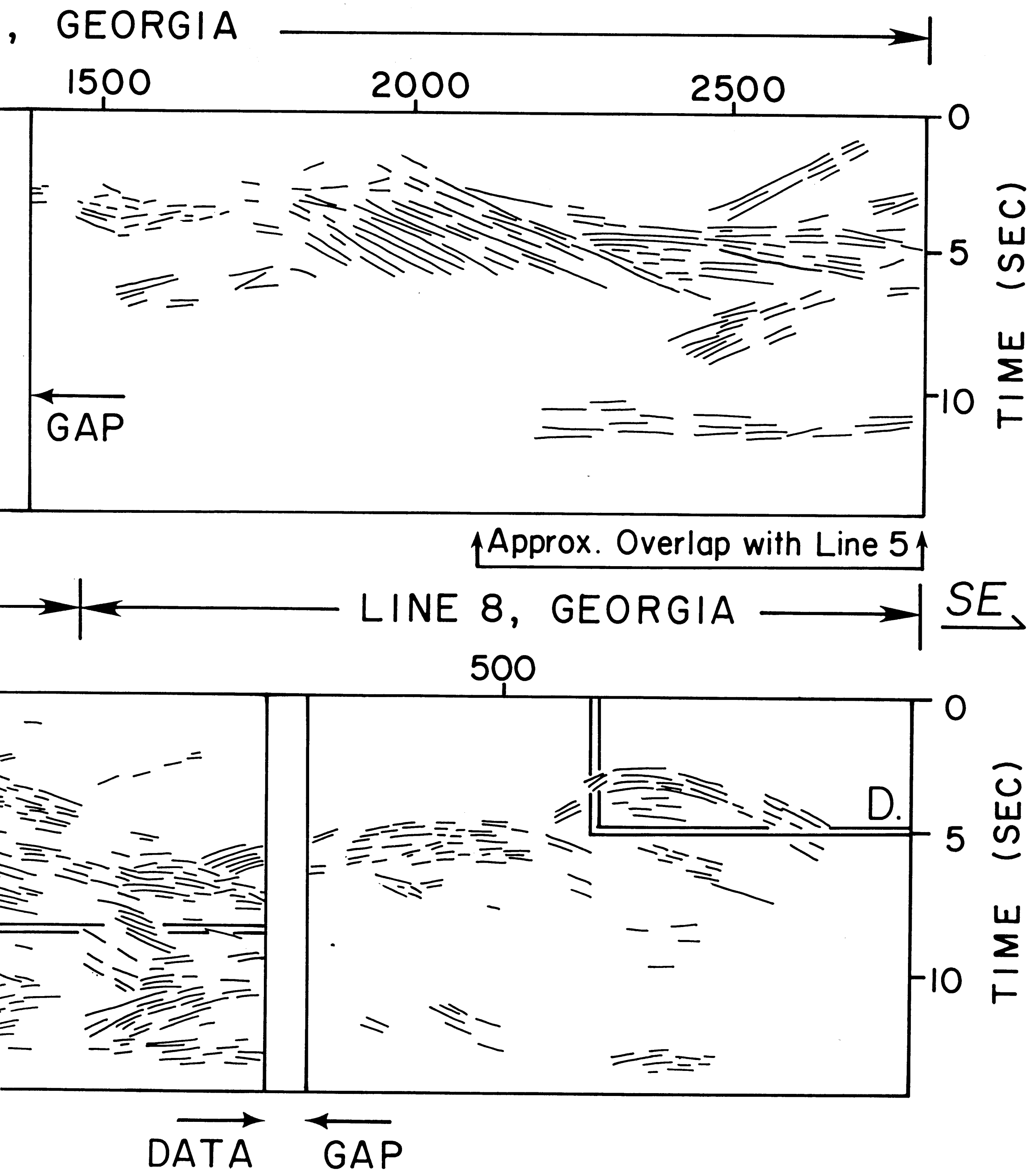

, GEORGIA
1500
2000
2500
0
5
10
TIME (SEC)
GAP
Approx. Overlap with Line 5
LINE 8, GEORGIA
SE
500
0
5
10
TIME (SEC)
D.
DATA
GAP

Fig 3, p. 3 of 3

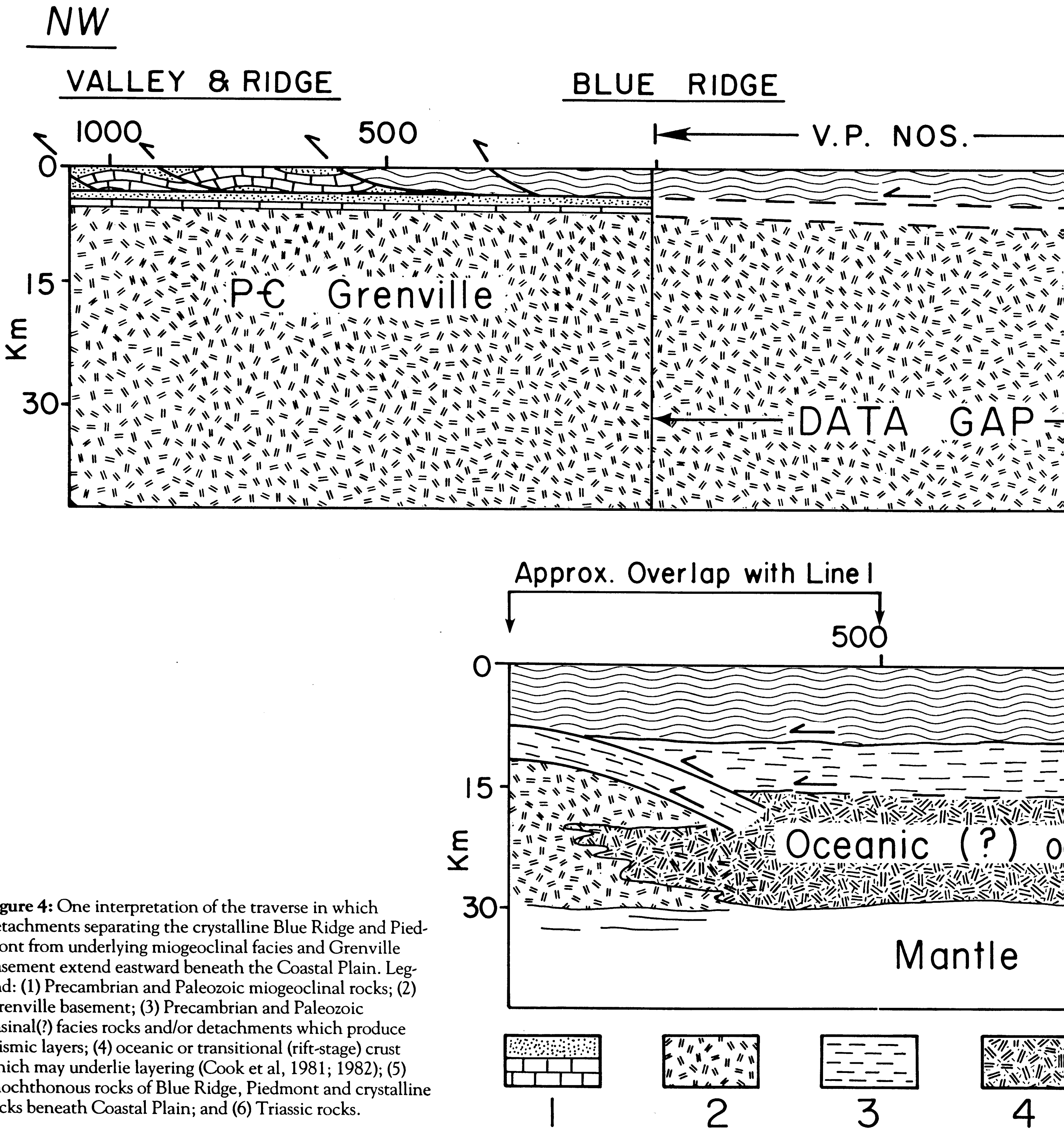
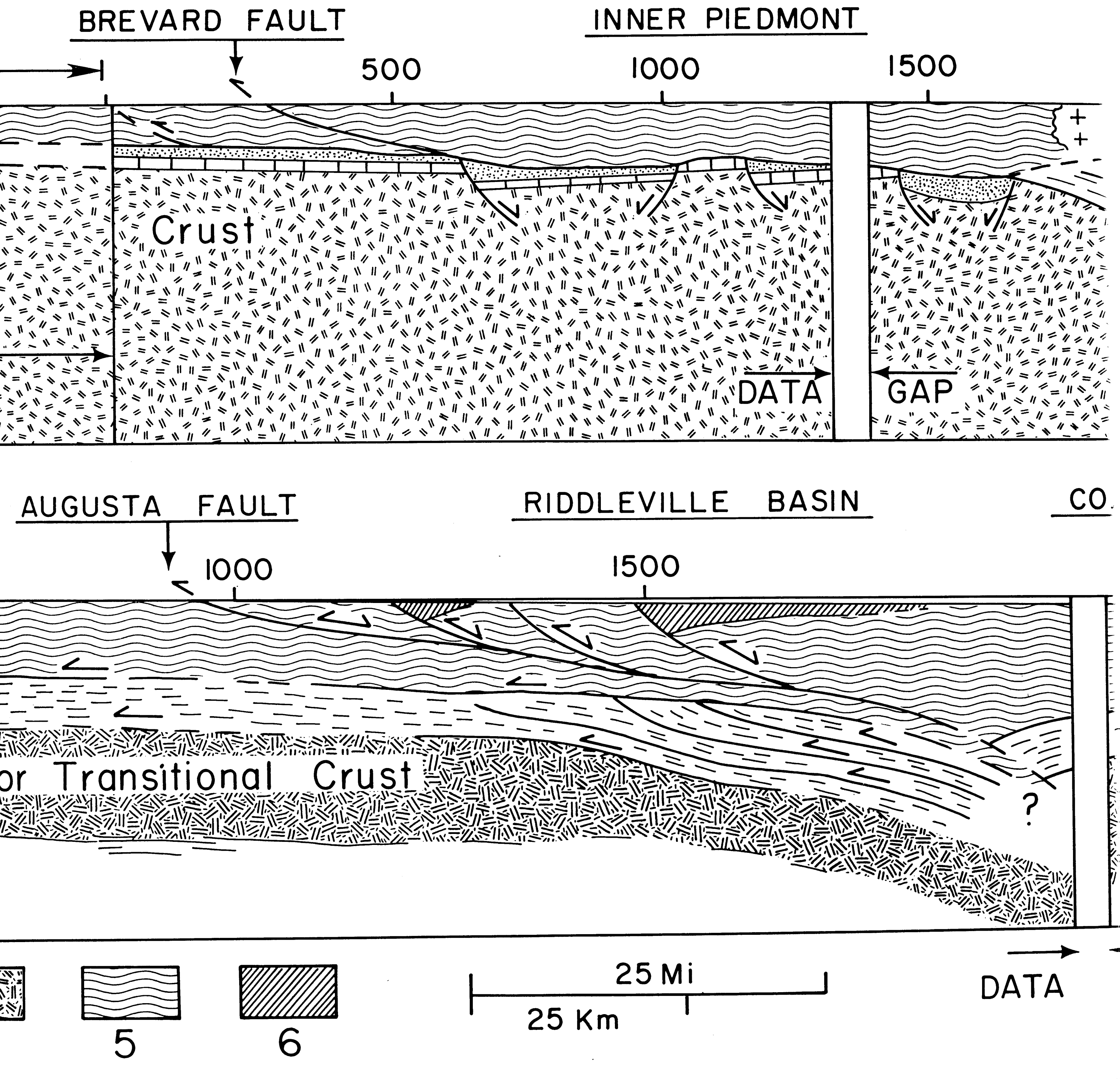


Figure 4: One interpretation of the traverse in which detachments separating the crystalline Blue Ridge and Piedmont from underlying miogeoclinal facies and Grenville basement extend eastward beneath the Coastal Plain. Legend: (1) Precambrian and Paleozoic miogeoclinal rocks; (2) Grenville basement; (3) Precambrian and Paleozoic basinal(?) facies rocks and/or detachments which produce seismic layers; (4) oceanic or transitional (rift-stage) crust which may underlie layering (Cook et al, 1981; 1982); (5) allochthonous rocks of Blue Ridge, Piedmont and crystalline rocks beneath Coastal Plain; and (6) Triassic rocks.


BREVARD FAULT
INNER PIEDMONT
500
1000
1500
+
+
Crust
DATA
GAP
AUGUSTA FAULT
RIDDLEVILLE BASIN
CO.
1000
1500
or Transitional Crust
?
5
6
25 Mi
25 Km
DATA

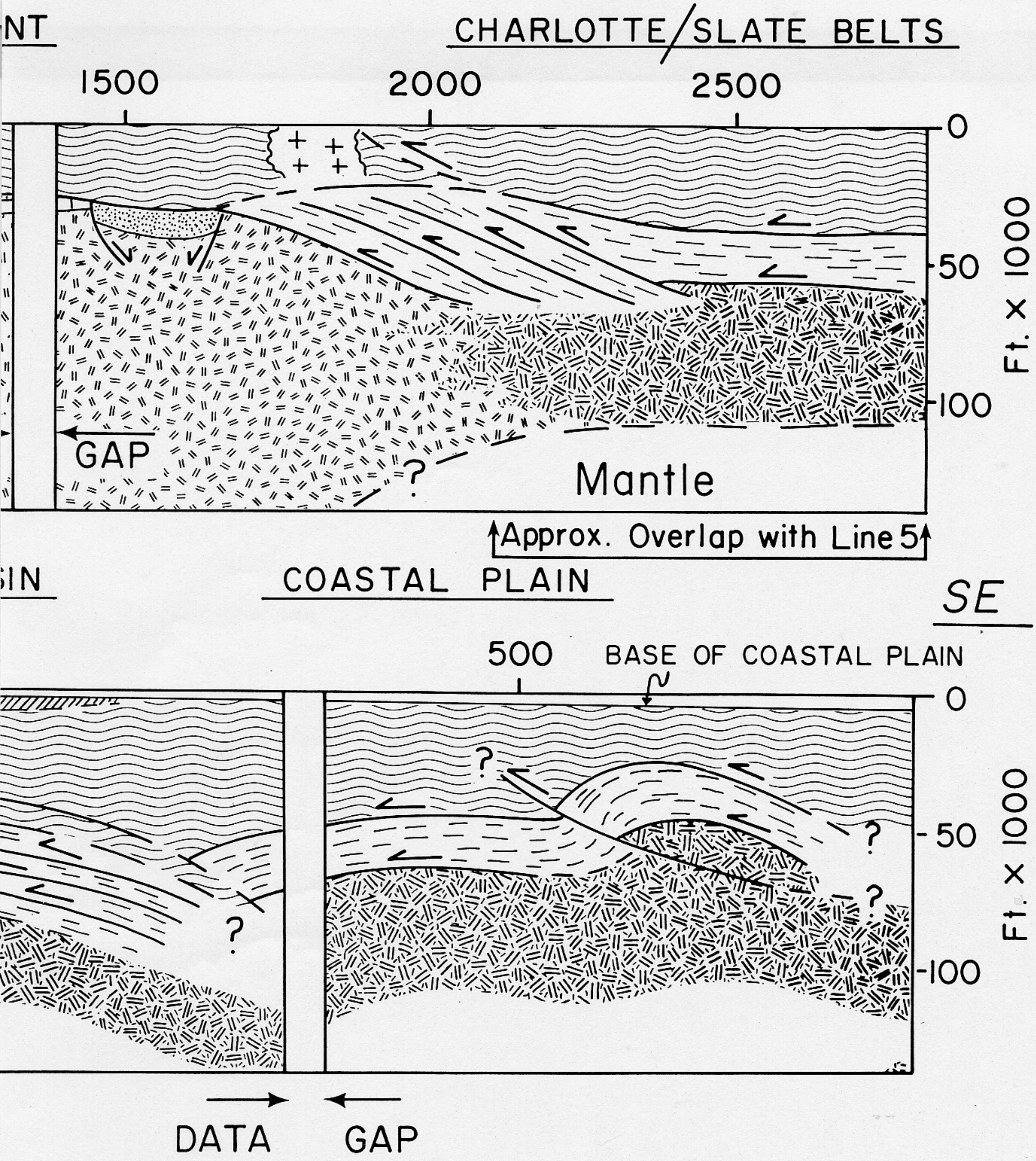

NT
CHARLOTTE/SLATE BELTS
1500
2000
2500
0
50
100
Ft. × 1000
GAP
?
Mantle
Approx. Overlap with Line 5
SIN
COASTAL PLAIN
SE
500
BASE OF COASTAL PLAIN
0
?
?
?
- 50
?
Ft. × 1000
-100
DATA
GAP

Fig 4, p. 1 of 3

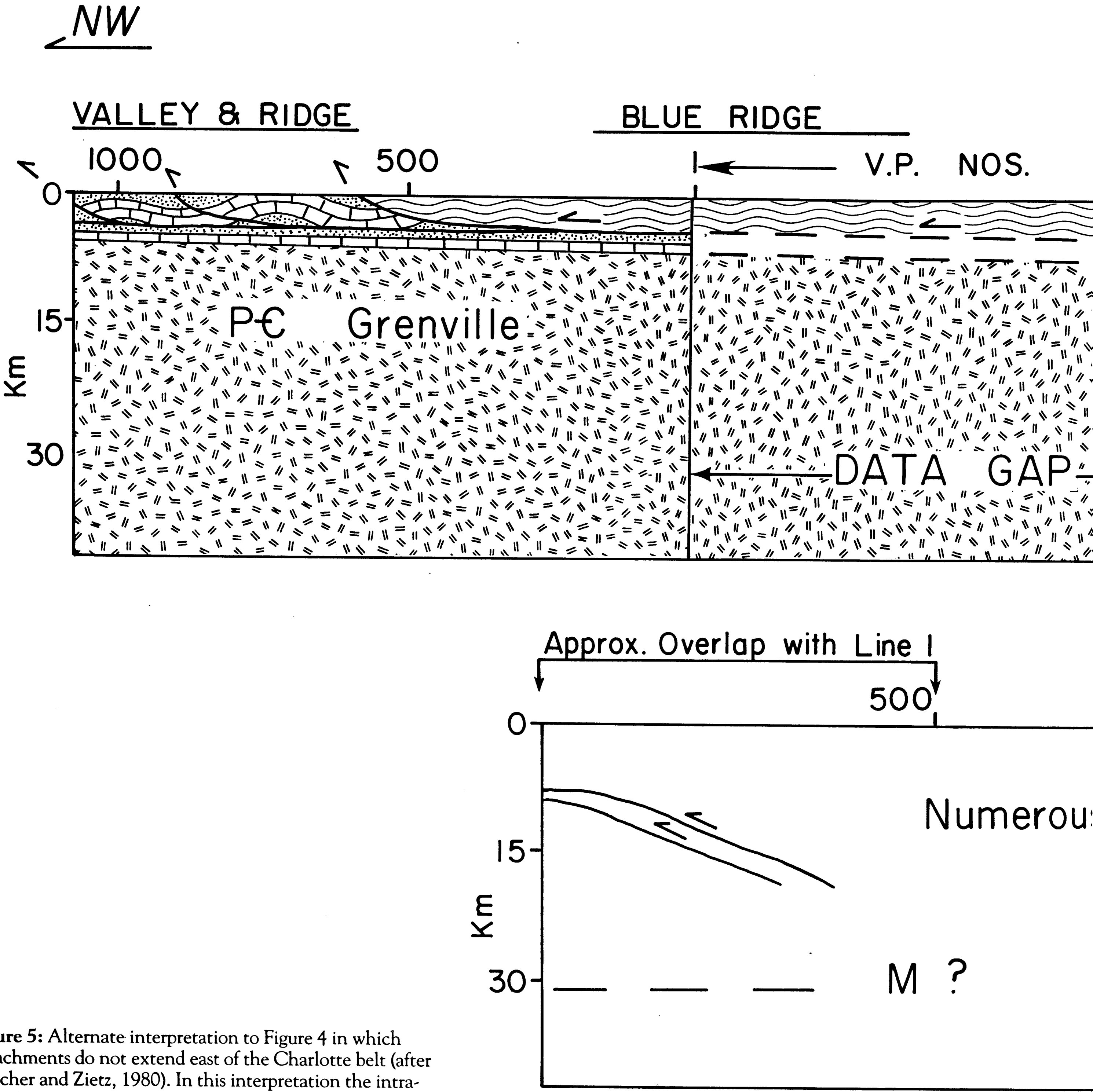
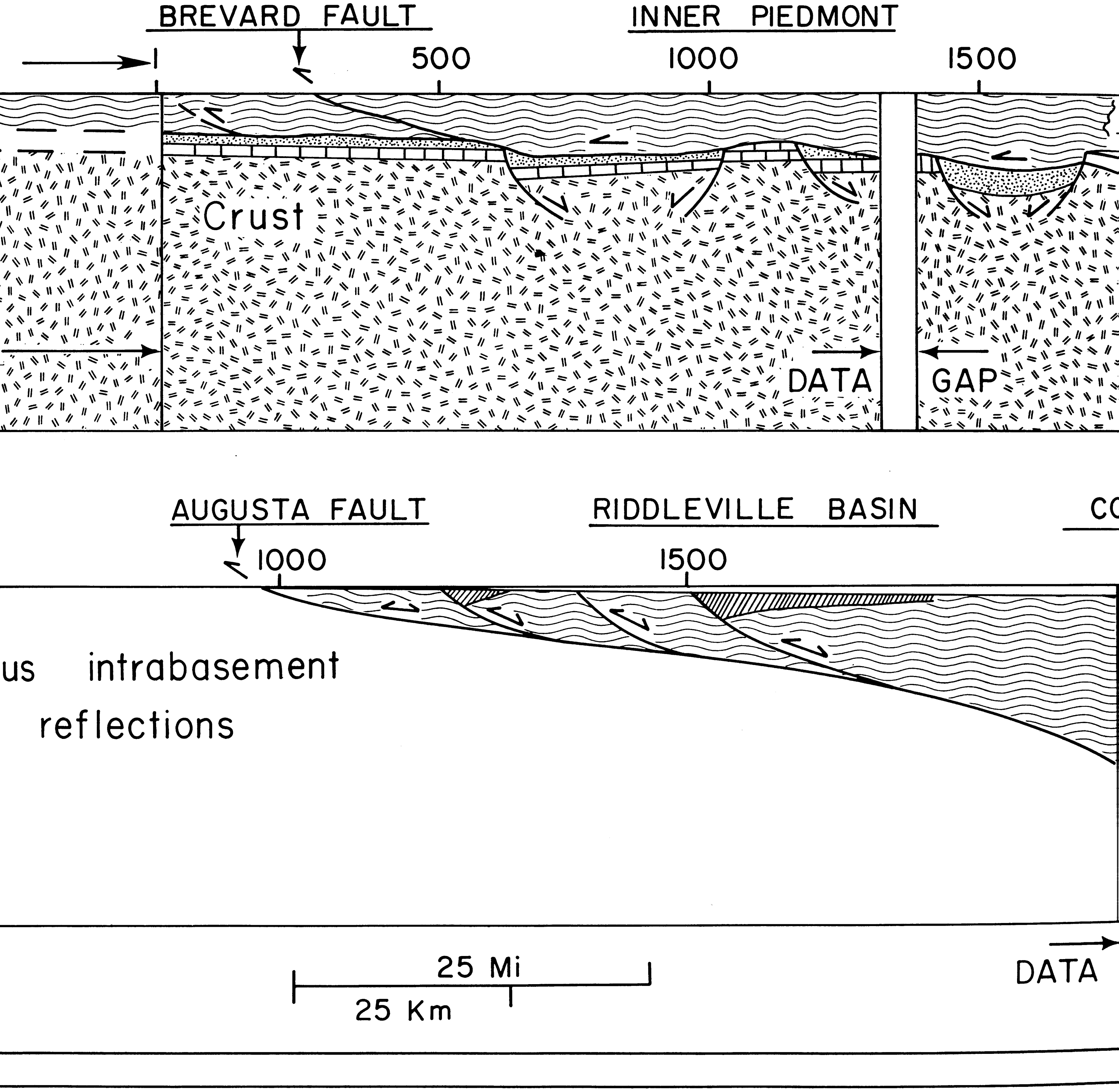


Figure 5: Alternate interpretation to Figure 4 in which detachments do not extend east of the Charlotte belt (after Hatcher and Zietz, 1980). In this interpretation the intracrustal layering observed east of the Charlotte belt could be interpreted in any number of ways. Rocks above Augusta fault are allochthonous as shown. Symbols are the same as in Figure 4.


BREVARD FAULT
INNER PIEDMONT
1
500
1000
1500
Crust
DATA
GAP
AUGUSTA FAULT
RIDDLEVILLE BASIN
CC
1000
1500
us intrabasement
reflections
25 Mi
25 Km
DATA

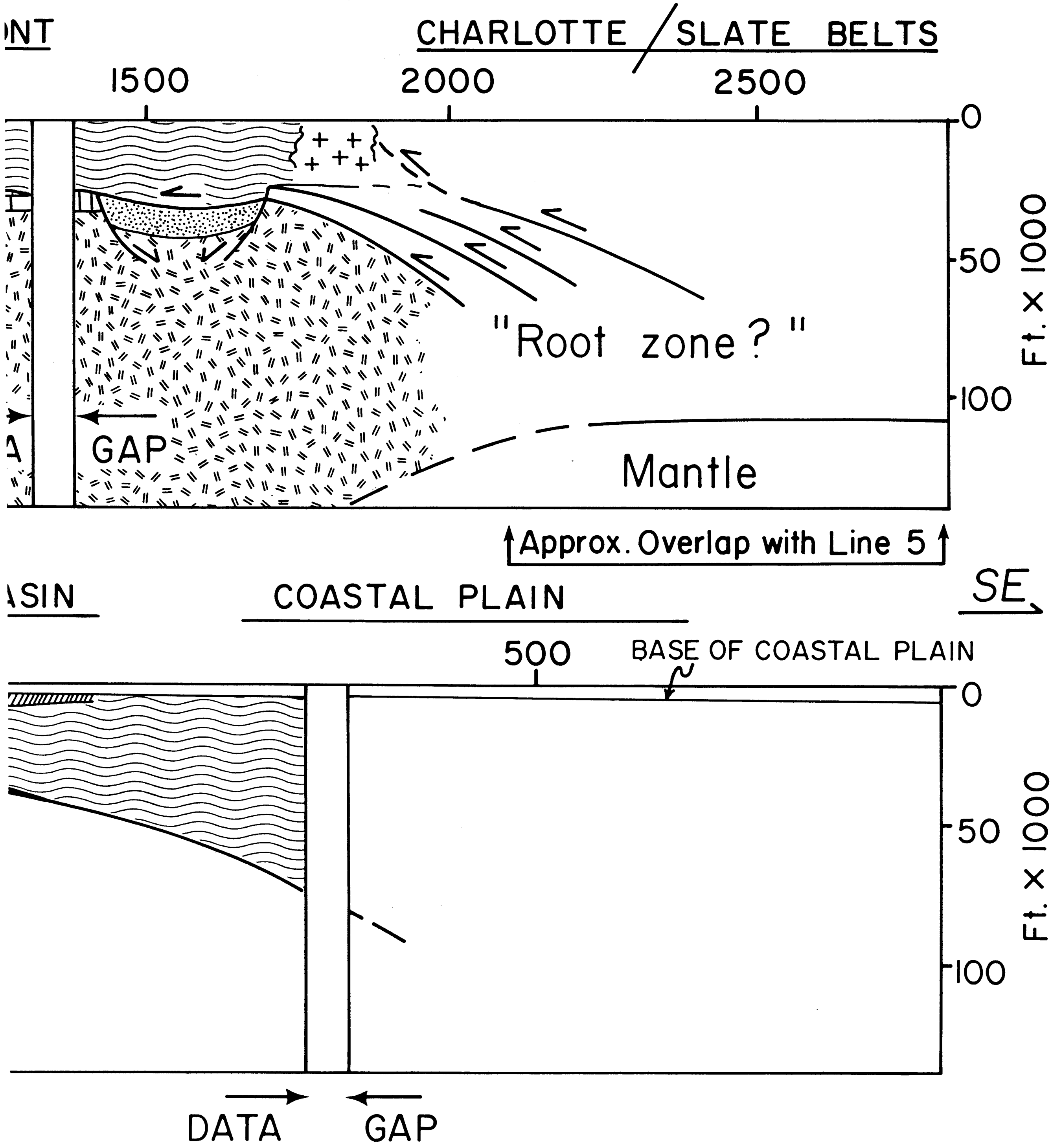

NT
CHARLOTTE / SLATE BELTS
1500
2000
2500
0
50
100
Ft. × 1000
"Root zone?"
GAP
Mantle
Approx. Overlap with Line 5
ASIN
COASTAL PLAIN
SE
500
BASE OF COASTAL PLAIN
0
50
100
Ft. × 1000
DATA
GAP

Fig 5, p. 3 of 3