Structure and Regional Tectonic Setting Across the Atlantic Coastal Plain of Northeastern Virginia as Interpreted From Reflection Seismic Data

by

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(ABSTRACT)

This study is a geophysical investigation that uses reflection seismic and potential field data to contribute to the development of a structural model of the North American Atlantic Passive Margin beneath the Atlantic Coastal Plain of northeastern Virginia. Specifically, this study focuses between 37.5° and 38.5° north latitude and 75.5° and 77.5° west longitude. The geophysical data include two seismic lines that were reprocessed at the Regional Geophysics Laboratory at Virginia Polytechnic Institute and State University. In addition, gravity modelling is performed in order to test the model developed from the seismic data.

Several important results have been achieved from this study. Lower Cretaceous fluvial sediments are less reflective than the overlying marine sequence. This observation is most obvious toward the east, particularly on line CF-1. Reverse faulting, which might be related to movement within the basement, is observed in at least one location on line NAB-11A, near Loretto, VA. Curiously, the dip is in the opposite direction of other reverse faults observed within the coastal plain.

The thickness of Triassic strata in the Taylorsville basin is constrained by seismic reflection data and gravity modelling. Results indicate that the basin is approximately 3 km deep. The strata within the basin appear to be poorly reflective except where they locally onlap the bottom of the basin, which is marked by a prominent reflector that is interpreted to be a diabase sill associated with Jurassic magmatism. In addition, the basin appears to be intruded by moderately dipping

dikes that were fed by the sill. The occurrence of basaltic material within the basin is confirmed by well log data.

Probably the most important result of this study is the tectonic implications of prominent, arcuate potential field anomalies and their relationships to changes in midcrustal reflectivity observed on the east side of line NAB-11A. Gravity modelling confirms the likelihood of a near-vertical, anomalous, mafic mass that extends to the Moho. This observation is supported by the loss of contiguous reflections in this area. A similar observation was made along the southern extension of the same anomaly by Çoruh and others (1988) who proposed that this feature is a dike swarm associated with Mesozoic rifting. It is proposed here that this body also could be an ancient Mesozoic magma chamber that collapsed during cooling after the Atlantic margin passed into the drift sequence.

Acknowledgements

I would like to thank John Costain for acting as my principal advisor and for offering a research topic of personal interest to me. His familiarity with geophysical and geological studies along the Atlantic continental margin, in addition to his suggestions for tectonic models, was invaluable. His rapid reviews of early versions of this manuscript also are appreciated. I also would like to thank Cahit Çoruh for acting as co-chairman on my committee. His extensive knowledge of seismic data processing techniques was invaluable for achieving the quality data presented in this study. His recommendations for a working tectonic model also are appreciated. Many thanks to Bob Milici for his active participation as my third committee member. He provided many enlightening conversations about data interpretation and possible structural models.

I am grateful to Mildred Mcmitt for all of the time that she spent helping me with DISCO programming, to Bob Montgomery for maintaining the VAX 11/785 and to John Wonderly for assistance on the IBM PC. Thanks also to Edwin Robinson for suggestions with regard to gravity modelling and to Lynn Glover III for his input on regional tectonics.

Finally, I would like to thank my wife Peggy for all of her love and encouragement. Her faith in me has been an inspiration.

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Introduction and Purpose of Study

This study is a geophysical investigation that uses reflection seismic data and potential field data to contribute to the development of a structural model of the North American Atlantic Passive Margin beneath the Atlantic Coastal Plain of northeastern Virginia (Figure 1). Specifically, the study area is located between 37.5^0 and 38.5^0 north latitude and 75.5^0 and 77.5^0 west longitude.

In spite of the numerous investigations conducted in this area, many questions about the subsurface geology persist. In particular, there is ambiguity with regard to the depth and geometry of the buried, Mesozoic Taylorsville basin as well as the geometry of the Hylas fault zone, along which the basin might have developed; there also is uncertainty about the hydrocarbon potential of the basin. In addition, there is no general agreement about the origin and tectonic significance of prominent arcuate potential field anomalies that straddle the Taylorsville basin. Furthermore, lateral variations in the thickness of the coastal plain sediments, in addition to the orientation of faults and associated structures, need clarification.

Geological data are limited to the small exposed part of the basin and to core holes within the Atlantic Coastal Plain. The integration of geophysical data and current geological data is essential to understanding the tectonic framework of the Atlantic continental margin. The geophysical data used in this study are comprised of two seismic lines (Figure 2) that were reprocessed at the Regional Geophysics Laboratory at Virginia Polytechnic Institute and State University with the Digicon Interactive Seismic Computer software package (DISCO v. 8.0; CogniSeis, 1990) on a VAX 11/785. Gravity modelling was performed on the Micro-innovations software package (1989).

Several important results are achieved by modelling the subsurface geology of the study area. Faulting within the coastal plain sediments is observed in at least one location. In addition, seismic and potential field data constrain the thickness of the Taylorsville basin strata. Finally, reflector geometries and their locations with respect to potential field data have significant tectonic implications.

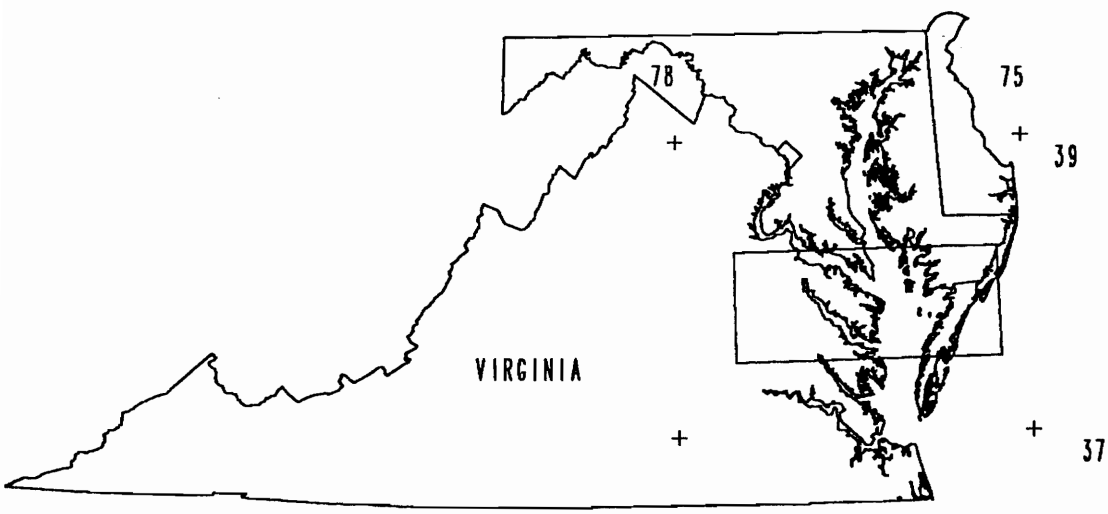


Figure 1. Study area: The study area is in the coastal plain of northeastern Virginia.

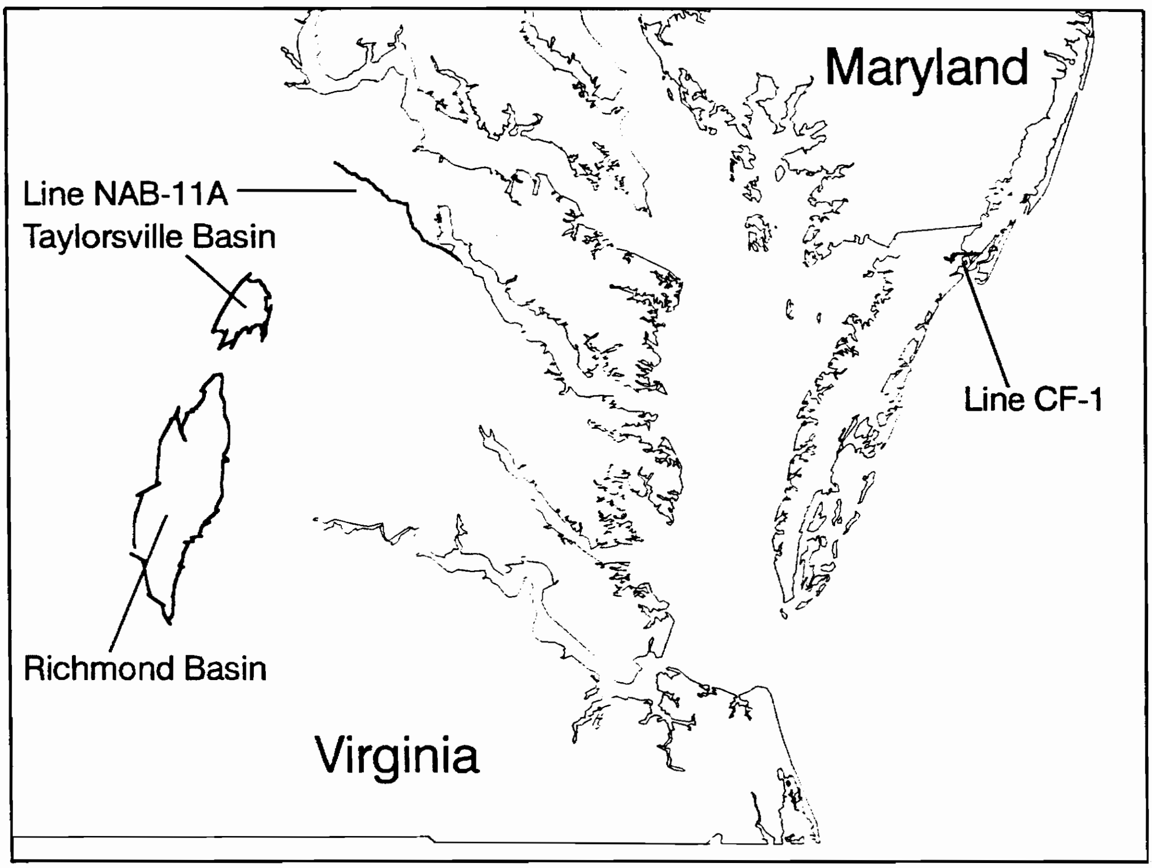


Figure 2. Location of seismic lines: Line NAB-11A parallels the Rappahannock River in VA and line CF-1 is west of Chincoteague, VA.

Geology

Tectonic History

The North American Atlantic continental margin is a passive margin that experienced numerous tectonic episodes throughout geologic time. The eastern U.S. is marked by the Appalachian mountain chain that developed as a result of multiple plate collisions during the Paleozoic (Klitgord et al., 1988). The Late Paleozoic Alleghanian orogeny resulted in the formation of the megacontinent Pangea. This event was followed by crustal extension that began in the Late Triassic forming a succession of independent basins that filled with sediments from the surrounding highlands (Van Houten, 1988). These basins extend 2000 km along the Appalachian Piedmont (Manspeizer and Cousminer, 1988; Figure 3). Rifting continued into the Early Jurassic during which time there was an episode of multiple basalt extrusions and diabase intrusions that lasted approximately 500,000 years (Manspeizer and Cousminer, 1988). This tectonic stage probably involved thermal doming and crustal attenuation due to considerable heating of the lower lithosphere (Keen and de Voogd, 1988; Manspeizer et al., 1988).

Since the Middle Jurassic, the Atlantic margin experienced significant subsidence on its eastern edge due to cooling of the lithosphere as it moved away from the spreading center. This criterion was used by Manspeizer and Cousminer (1988) to indicate that the margin has been in a

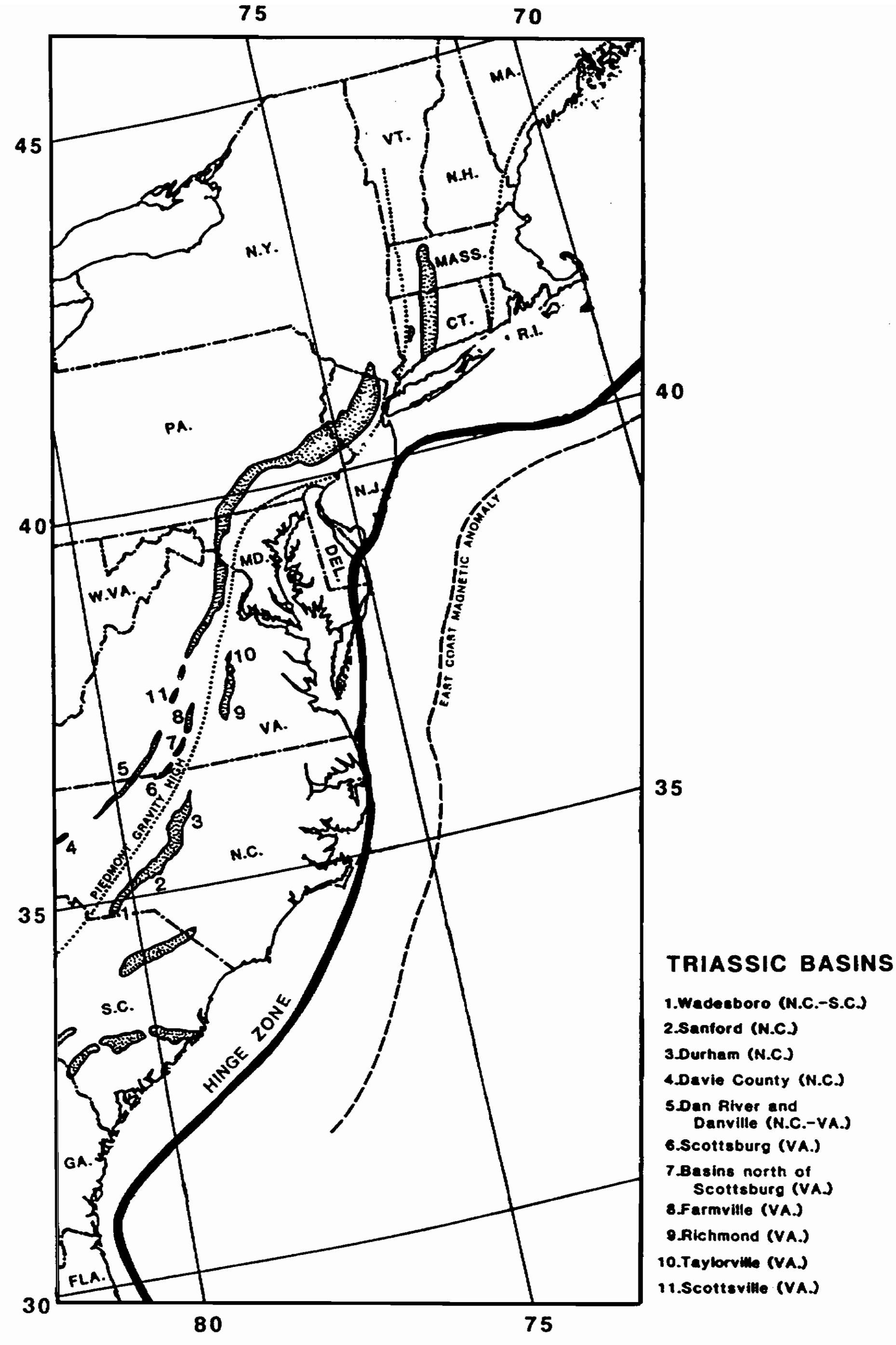


Figure 3. **Mesozoic rift basins:** Map of the North American Atlantic Passive Margin illustrating exposed Mesozoic rift basins. Modified after Manspeizer and Cousminer, 1988.

drift stage that continues today. The disconformity in the geologic record that marks this tectonic transition is referred to as the postrift unconformity.

The most western deep crustal penetrating faults associated with Mesozoic rifting mark the landward limit of the rifted continental crust that has been stretched and faulted. The basement hinge zone marks the eastward limit (Klitgord et al., 1988). The basement hinge zone is the landward edge of marginal sedimentary basins where basement deepens rapidly in the seaward direction (Klitgord et al., 1988). A variety of structures, which include rotated half-grabens bounded by seaward dipping border faults, tilted blocks bounded by landward dipping faults and thick sedimentary wedge sequences, are associated with the hinge zone along the Atlantic margin (Klitgord et al., 1988).

The Taylorsville Basin

The Hylas zone, which forms the western boundary of the Taylorsville basin and which is exposed in Goochland and Hanover Counties, is a fault zone that underwent at least 2 deformations (Bobyarchick and Glover, 1979). Dextral shearing began in the ductile regime following the emplacement of the Late Alleghanian Petersburg granite (Gates and Glover, 1989). This deformation moved into the brittle-ductile regime before ceasing sometime in the Permian. During the Mesozoic, the Taylorsville basin probably formed along the preexisting Hylas fault as a result of reactivation in the brittle regime.

The Taylorsville basin contains Carnian age rocks (Manspeizer and Cousminer, 1988) that comprise the Doswell Formation (Weems, 1980; Table 1). This formation, which is restricted to the Taylorsville basin, has three members. The Stagg Creek Member is a massive sandstone and conglomerate that nonconformably overlies the Petersburg granite on the southeast side of the basin and nonconformably overlies undifferentiated metaigneous and metasedimentary rocks on the north and northwest side of the basin (Mixon et al., 1989). The Falling Creek Member, which lies conformably over the Stagg Creek Member, is composed of flaggy, laminated sandstone. In addition, green siltstone and green, gray and black shale are common. Coal also has been documented in this member (Weems, 1980). The Newfound Member, which is the uppermost member of the Doswell Formation, is composed of a conglomeratic facies that intertongues with a fine grained facies. The conglomeratic facies also contains massive and crossbedded sandstones. The fine grained facies contains massive, red and light brown siltstone. The top of this member consists mostly of semi-consolidated breccias. On the basis of color transformation of palynomorphs, the Taylorsville basin is considered to contain thermally mature strata of type I, and possibly type III, kerogen (Milici et al., 1991). The abundance of coarse grained reservoirs within the Taylorsville basin indicates a potential for hydrocarbon recovery in the lower part of the basin. Texaco has explored for hydrocarbons in the northern part of the basin (Petzet, 1992; Shen, 1992). Several dry wells, including one as deep as 10,135 feet, have been drilled (Petzet, 1992).

The Fork Church fault is a prominent fault that produced drape folding in the Falling Creek Member on the northwest side of the basin. In addition, synclines and monoclinal structures are observed within the Newfound Member (Weems, 1980). It is possible that en echelon faulting observed in the Richmond basin also is present in the Taylorsville basin (Weems, 1980).

The Taylorsville basin strata have been intruded by north and northwest trending diabase dikes that do not extend beyond the basin margins (Weems, 1980). Igneous rocks found in Newark type basins of the central and northern Appalachians are high-Ti, quartz-normative, tholeitic basalts or diabases (de Boer et al., 1988). Basalt flows generally are restricted to the area between Nova Scotia and Virginia, while intrusive equivalents are distributed between Newfoundland and Alabama (Manspeizer et al., 1988). No flows or sills were recognized in the Taylorsville basin by Weems (1980).

The Atlantic Coastal Plain

The Atlantic Coastal Plain is represented by a sequence of exposed Cretaceous and Tertiary sediments that unconformably overly Triassic strata and crystalline basement rocks. The Lower

Table 1. Stratigraphy of the Taylorsville Basin (After Weems, 1980)

Age		Name			Character
TRIASSIC	Late Carnian	Doswell Formation	Newfound Member	siltstone/ sandstone facies	Siltstones, massive, and sandstones, massive, poorly consolidated, rare conglomerates except in top several hundred feet.
TRIASSIC	Late Carnian	Doswell Formation	Newfound Member	sandstone/ conglomerate facies	Sandstones and conglomerates, massively cross-bedded, well consolidated, rare siltstone lenses.
TRIASSIC	Middle Carnian	Doswell Formation	Falling Creek Member		Sandstones, well bedded and flaggy, and shales, gray to black, fissile, some siltstones and rare coals. Sandstones and shales commonly calcareous.
TRIASSIC	Middle Carnian	Doswell Formation	Stagg Creek Member		Sandstones, massive to massively crossbedded, and conglomerates, massive, rare siltstone lenses.

Cretaceous coastal plain is dominated by fluvial deposits. Locally, marine deposits have been identified on the basis of paleontological data (Olsson et al., 1988). A marine transgression, which began in the Upper Cretaceous (Albian) resulted in extensive deposition of beach sands and lagoon, marsh and delta front deposits (Olsson et al., 1988).

The coastal plain of northeastern Virginia is cut by northeast-trending, northwest-dipping, high-angle, en echelon, reverse faults (Mixon and Newell, 1977). This fault system, referred to as the Stafford fault system (Mixon and Newell, 1977), exhibits 15 to 60 meter offsets. On the basis of structure-contour maps of Cretaceous and Paleocene lithostratigraphic units, which indicate recurrent movement along this fault system, most of the deformation is interpreted to have taken place in Cretaceous to Middle Tertiary time.

Data Acquisition and Processing

The seismic data used in this study are comprised of two seismic lines that were reprocessed using the Digicon Interactive Seismic Computer software package (DISCO v. 8.0; CogniSeis, 1990) on a VAX 11/785. Seismic reflection profile NAB-11A, which was shot over the Taylorsville basin by Teledyne Exploration Inc. along U.S. route 17 between Tappahannock and Port Royal, and seismic profile CF-1, which was shot east of NAB-11A by Geophysical Services Inc. (GSI), along state route 175 west of Chincoteague, are the primary structural constraints (Figure 2).

A typical processing sequence was performed on both line NAB-11A and line CF-1. One of the less common processing steps applied to line NAB-11A was vibroseis whitening before crosscorrelation. This step was performed in order to correct for amplitude decay (Çoruh and Costain, 1983). Extensive tests indicated that vibroseis whitening of line CF-1 was not necessary because amplitudes were balanced in the field by diversity stacking. Extended correlation (Pratt, 1982), which provided 12 second and 13 second record sections for lines NAB-11A and CF-1, respectively, also was performed. Lastly, many of the seismic sections are presented in automatic line drawing format (Çoruh et al., 1988). This step was applied to the data to enhance deep reflections that were not evident on the conventional displays.

In addition to the seismic data, gravity modelling was performed. The gravity profile along NAB-11A was obtained from a Bouguer anomaly map of the Atlantic Coastal Plain (Johnson, 1973). Because the regional anomaly in the area of line NAB-11A is approximately zero (James et al., 1968), no regional anomaly was removed before gravity modelling. The Micro-innovations modelling package (1989) uses the algorithm derived by Talwani and others (1959).

Line NAB-11A

Line NAB-11A is a 34 km long line that was shot from southeast to northwest as a 120 channel symmetrical split spread. Four Y600LF vibrators were used to transmit 10-80 Hz, 7 second sweeps that were recorded for 13 seconds at a sampling interval of 2 milliseconds. Geophones were set in-line at 24 phones per group at a spacing of 5 feet and a group interval of 110 feet (Table 2).

A flow chart of the processing steps and processing parameters used to obtain the final stacked section of line NAB-11A is provided below:

1. Demultiplex field tapes
2. Vibroseis whitening (AGC window= 1000 ms), resample to 4 ms and perform extended correlation to 12 seconds
3. Define line geometry
4. Calculate datum statics

    Datum elevation = 25 m

    Datum velocity = 1.68 km/sec

5. Edit bad traces
6. Perform CDP sort and apply datum statics
7. Deconvolve CDP traces

    Gap = 32 ms

    Variable design and application gates

    a. Design gate = 100-1200 ms

        Filter length = 80 ms

        Application gate = 0-3000 ms

    b. Design gate = 3000-4000/4300-6000 ms interpolation

        Filter length = 160 ms

        Application gate = 3000-11000 ms

8. Correct for NMO
9. Apply spatially varying hand picked mutes
10. Bandpass filter 14-19-70-80 Hz
11. Iteratively determine velocity and residual statics

    3 passes of residual statics, 4 iterations each

    3 passes of velocity functions
12. Stack
13. Bandpass filter 14-19-70-80 Hz
14. Migrate to 5000 ms using the finite-difference method

    Velocity = 85% of stacking velocity

    Layer thickness = 40 ms

Line CF-1

Line CF-1 is a 10 km long line that was shot from southeast to northwest as a 48 channel push spread. Three vibrators were used to transmit 12-96 Hz, 10 second sweeps that were recorded for 15 seconds at a sampling interval of 4 ms. Twenty four geophones per group were laid out at a group interval of 110 feet (Table 2).

A flow chart of the specific processing parameters used to produce the final stacked section of line CF-1 is provided below:

1. Demultiplex field tapes
2. Perform extended correlation to 13 seconds
3. Define line geometry
4. Calculate datum statics

    Datum elevation = 9 m

    Datum velocity varies spatially between 1.0 km/s and 2.6 km/s
5. Edit bad traces
6. Perform CDP sort and apply datum statics
7. Deconvolve CDP traces

Gap = 32 ms

Design gate = 250-2400 ms

Filter length = 1600 ms

Application gate = 0-12000 ms

8. Correct for NMO
9. Apply spatially varying hand picked mutes
10. Bandpass filter 12-17-85-96 Hz
11. Iteratively determine velocity and residual statics

    2 passes of residual statics, 4 iterations each

    3 passes of velocity functions
12. Stack
13. Bandpass filter 14-20-85-96 Hz
14. Migrate using the finite-difference method

    Velocity = 90% of stacking velocity

    Layer thickness = 40 ms

Table 2. Acquisition parameters for lines NAB-11A and CF-1

Parameters	NAB-11A	CF-1
Year acquired	1986	1979
vibrators	4	3
sweep frequencies	10-80 Hz	12-96 Hz
sweep length	7 sec	10 sec
source interval	110′	110′
group interval	110′	110′
number of channels	120	48
sample interval	2 ms	4 ms
record length	13 sec	15 sec
spread configuration (feet)	split 6820-330-330-6820	push 5500-330

Discussion

Deep Crustal Reflections

All of the seismic sections provided in the discussion are presented at 1:1 scale. A considerable number of midcrustal reflections, which occur as deep as 5 seconds, are observed on the automatic line drawing of line NAB-11A (Figure 4). All sections are presented at 1:1 scale. A reasonably contiguous set of reflections persists across most of the line from approximately 2 seconds (~ 3 km deep) at station 1198 to 4 seconds (~ 8 km deep) at station 300 where they abruptly terminate (Figure 5). These reflections are interpreted to originate from mylonites associated with the Hylas fault zone. The dip of these reflections on the west part of the line would project to the surface approximately 15 km west of the end of the line where the Hylas fault zone is exposed (Mixon et al., 1989). A deeper set of reflections of unknown origin (Figure 5) is interpreted to originate from another decollement of Paleozoic age. Whether reactivation on this surface occurred during the Mesozoic can not be determined from the seismic data but is probable on the basis of the tectonic history of the Hylas fault zone and other exposed Paleozoic faults that border Mesozoic basins (Ratcliffe et al., 1986; Gates and Glover, 1989). It also is possible that both sets of reflections represent the entire Hylas zone, which would be approximately 4 km thick.

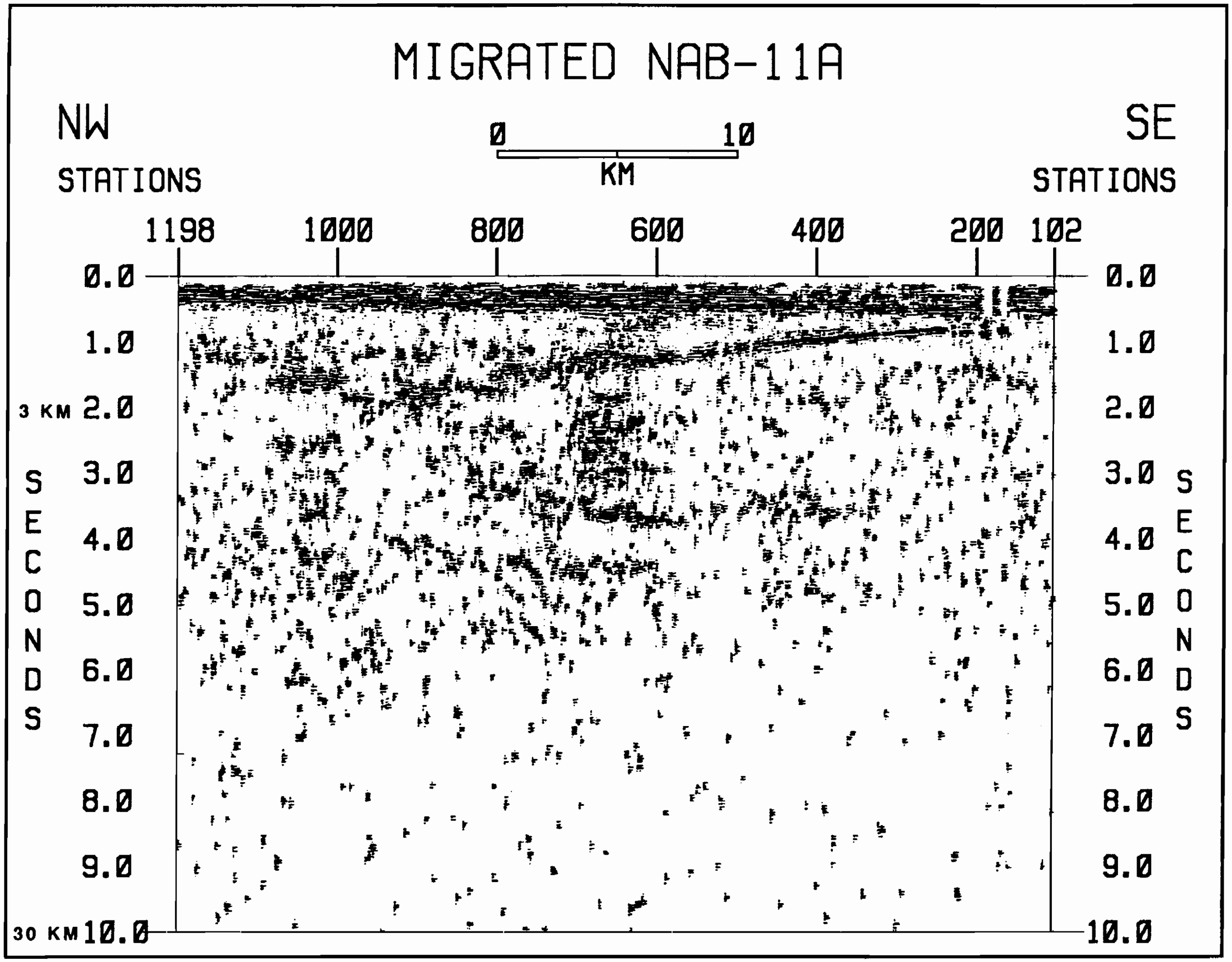


Figure 4. Uninterpreted line drawing of line NAB-11A: A line drawing of line NAB-11A reveals contiguous midcrustal reflections but no deep crustal reflections that might identify Moho.

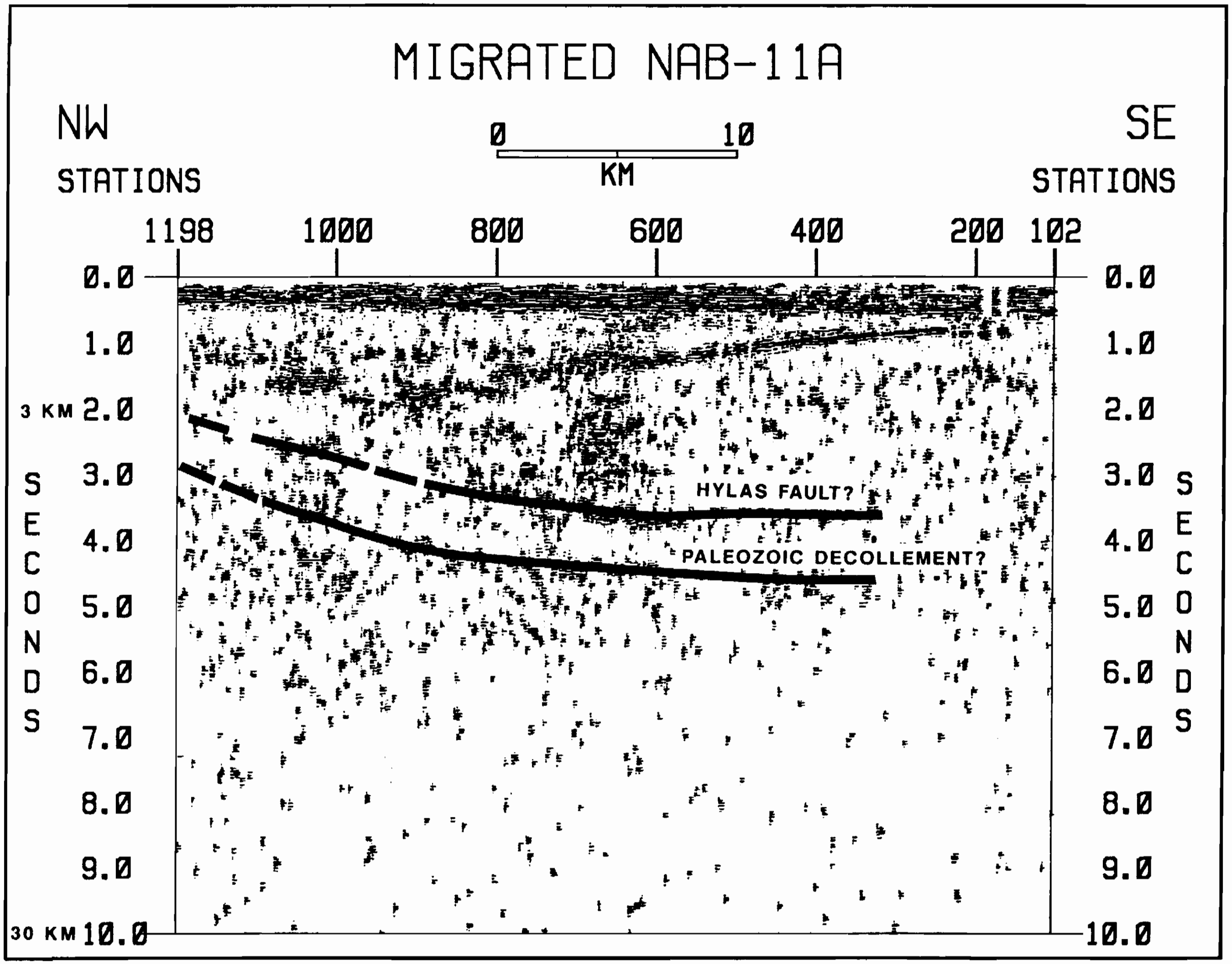


Figure 5. **Interpreted midcrustal reflections:** The Hylas fault may extend as deep as 4 seconds, or approximately 8 km. A deeper set of midcrustal reflections may represent a Paleozoic decollement or also be related to the Hylas fault zone.

No deeper crustal reflections are observed on line NAB-11A (Figure 4). In addition, no midcrustal or deep crustal reflections are seen on line CF-1 (Figure 6). The characteristically non-reflective crust observed on both lines also is seen on corresponding sections of regional vibroseis line I-64 to the south (Figure 7). Both line NAB-11A and line CF-1 correlate along strike with the non-reflective zones observed on line I-64. The Moho is not imaged on any of the seismic lines below these zones of non-reflectivity. A discussion of this change in reflectivity is presented below.

Relationship of Potential Field Anomalies to Changes in Reflectivity

There is a significant change in reflectivity associated with gravity and magnetic anomalies (Figures 8 and 9) on the east side of line NAB-11A (Figure 10). These anomalies are approximately 200 km long and extend as far north as the Potomac River, east of Fredericksburg, VA, and as far south as the Nottaway River, southeast of Petersburg, VA. There also is a change in reflectivity on line I-64 (Figure 7) where it crosses the southern extension of the same, arcuate potential field anomalies. This correlation was interpreted by Çoruh and others (1988) to be a dike swarm associated with Mesozoic rifting. The symmetry of both the gravity and magnetic anomalies suggests that the anomalous source is steeply dipping or vertical. Gravity modelling, which will be discussed later, was performed in order to test this interpretation.

The Taylorsville Basin

The bottom of the Taylorsville basin is marked by a strong, northwest dipping reflection that extends as deep as 2.0 seconds or approximately 3 km (Figure 11). This reflection is interpreted to originate from a diabase sill associated with the episode of Jurassic magmatism observed in other Mesozoic basins (deBoer, 1988; Manspeizer and Cousminer, 1988). Above this horizon, the basin appears to be filled by relatively non-reflective sedimentary rocks that locally onlap the bottom of the basin (Figure 12). Previous studies indicate that many buried Mesozoic basins typically are

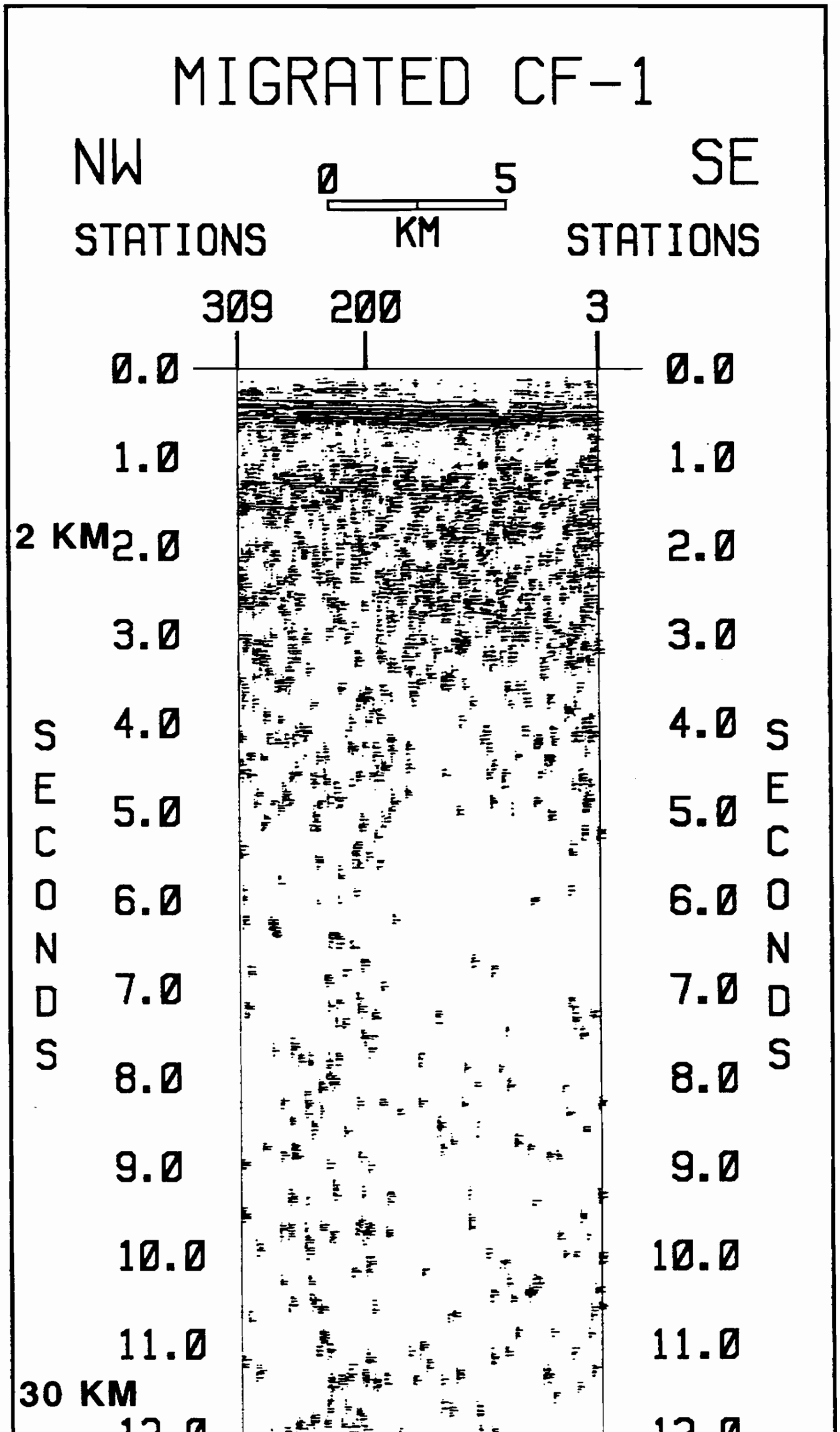


Figure 6. **Uninterpreted line drawing of line CF-1:** No midcrustal or deep crustal reflections are present on line CF-1. Coastal plain sediments extend as deep as 1.9 seconds.

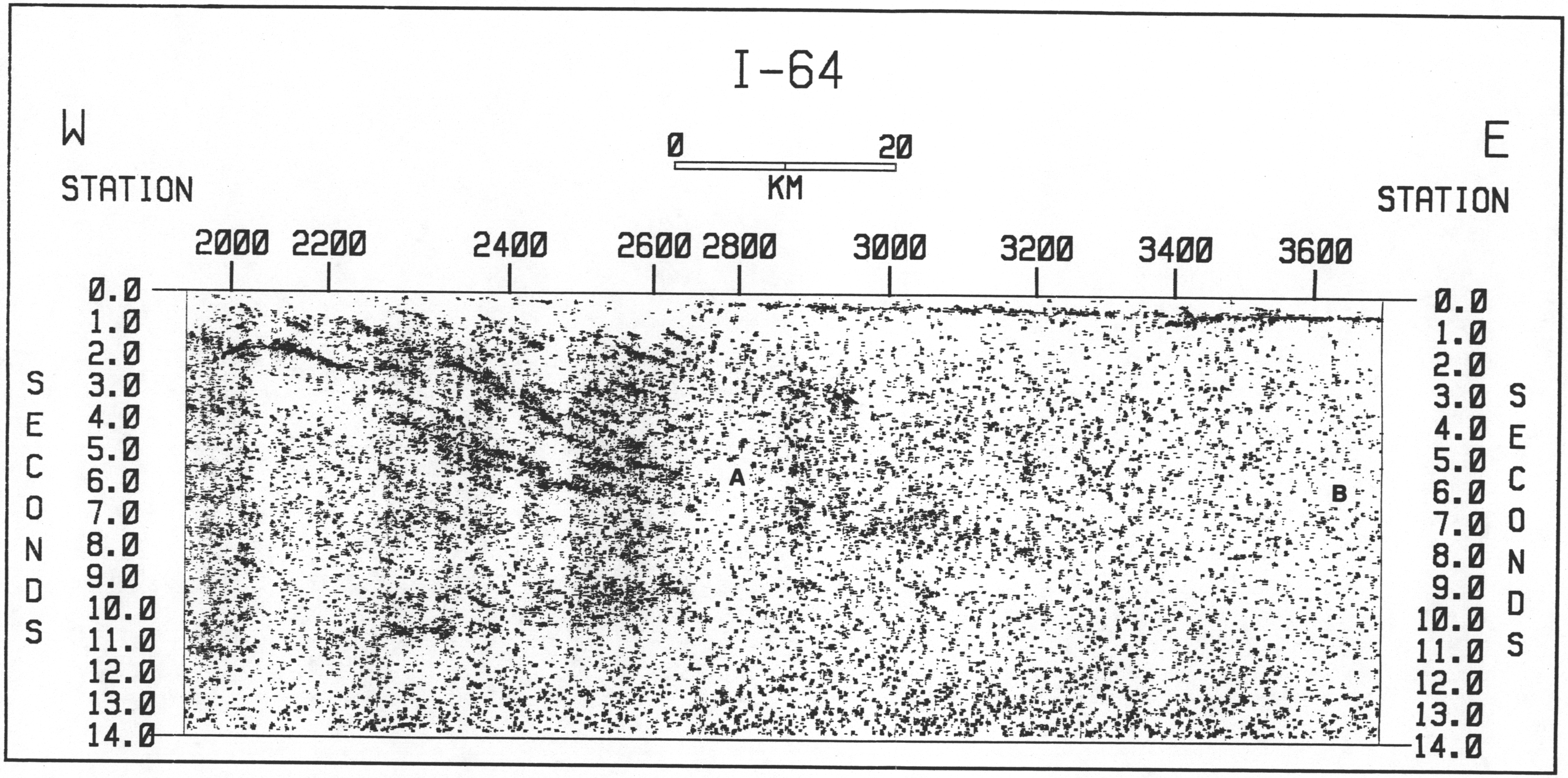


Figure 7. Line drawing of line I-64: Line I-64 also has non-reflective zones where it correlates along strike with line NAB-11A (A) and line CF-1 (B).

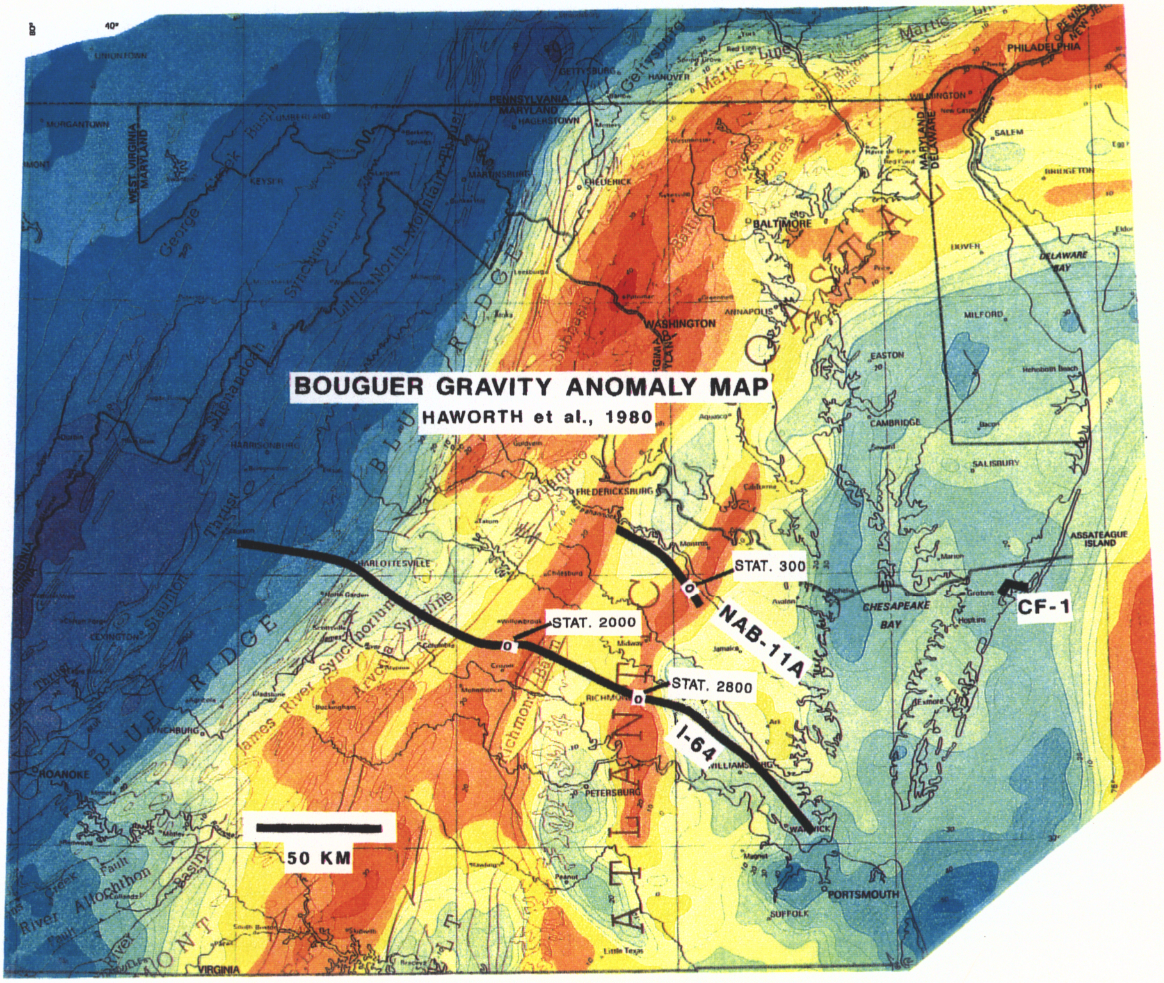


Figure 8. **Gravity anomaly map:** Line NAB-11A and line I-64 cross different parts of the same gravity anomaly.

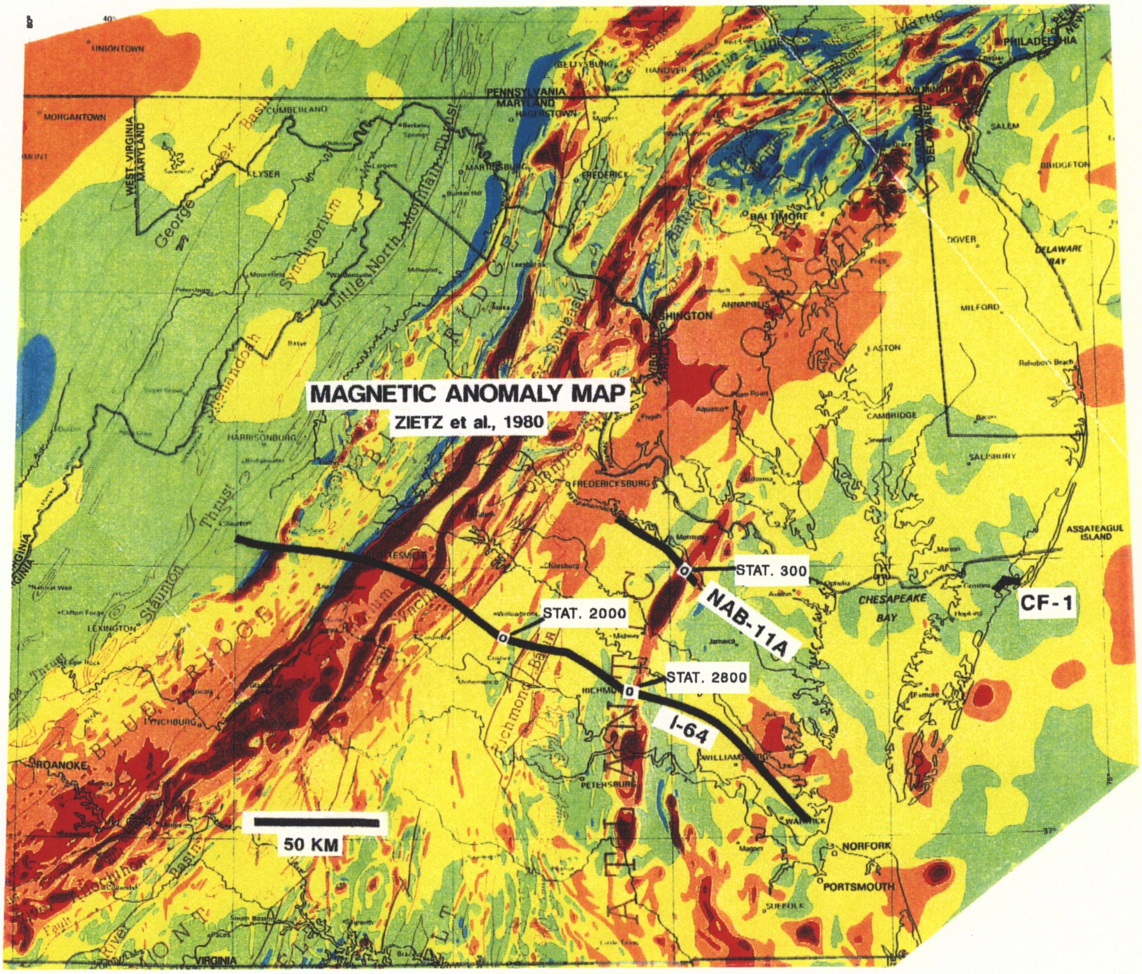


Figure 9. Magnetic anomaly map: Line NAB-11A and line I-64 cross different parts of the same magnetic anomaly.

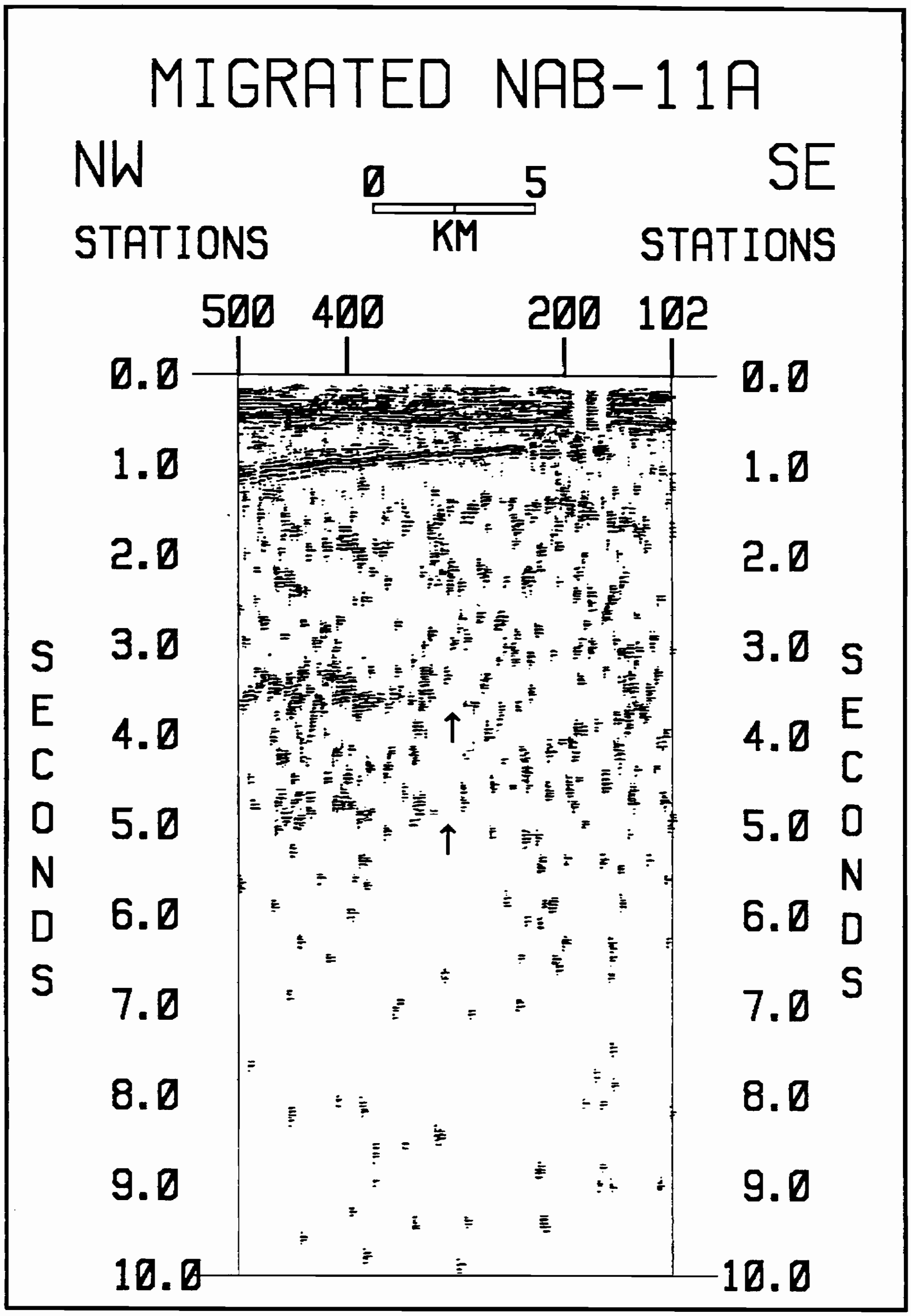


Figure 10. Change in reflectivity on line NAB-11A: There is a noticeable loss of continuity of the midcrustal reflections (arrows) where line NAB-11A crosses the potential field anomalies.

non-reflective (Costain et al., 1992). In addition, onlapping was observed in the Newark and Richmond basins (Schlische and Olsen, 1990). Extensive normal faulting appears to have taken place west of station 800 (Figure 13). Evidence of faulting mostly is supported by a loss of continuity of the strong basal reflection in this area. These faults probably are related to Mesozoic rifting.

The Taylorsville basin strata are cut by several, strongly reflective, dipping events that are interpreted to be dikes fed by the underlying sill. These features are most prominent between stations 400 and 700 (Figure 14) but do exist further west near stations 900 through 1000 (Figure 15). In order to determine whether these features are real reflections or diffracted energy, modelling was performed using the AIMS seismic modelling software package (1985). One hundred synthetic shots were generated using the same shooting parameters that were used to acquire line NAB-11A. Velocities of 1800 m/s and 4500 m/s were used to represent the coastal plain sediments and the Triassic strata, respectively. An example of the ray paths generated by the model is shown in Figure 16. In addition, a synthetic shot and an actual shot near station 1025 are provided for comparison (Figure 17). The synthetic shot contains abundant diffracted energy. A synthetic CDP and an actual CDP also are offered for comparison (Figure 18). As with the shot data, the synthetic CDPs contain abundant diffracted energy. Finally, a comparison of the stacked synthetic data and the stacked real data (Figure 19) clearly illustrates that any diffracted energy in the real data must have a steeper dip than that of the features observed on line NAB-11A near stations 900 through 1000. As expected (Yilmaz, 1987), migration of the data has compressed the reflections, steepened the dip of the reflections and moved them up in time (Figure 20). If these features were diffractions, the migration process would have collapsed the diffractions to their proper spatial and temporal locations and they would not have remained in the data. The interpretation presented here also is supported by boreholes that have encountered basaltic material (Milici et al., 1991; Figure 21).

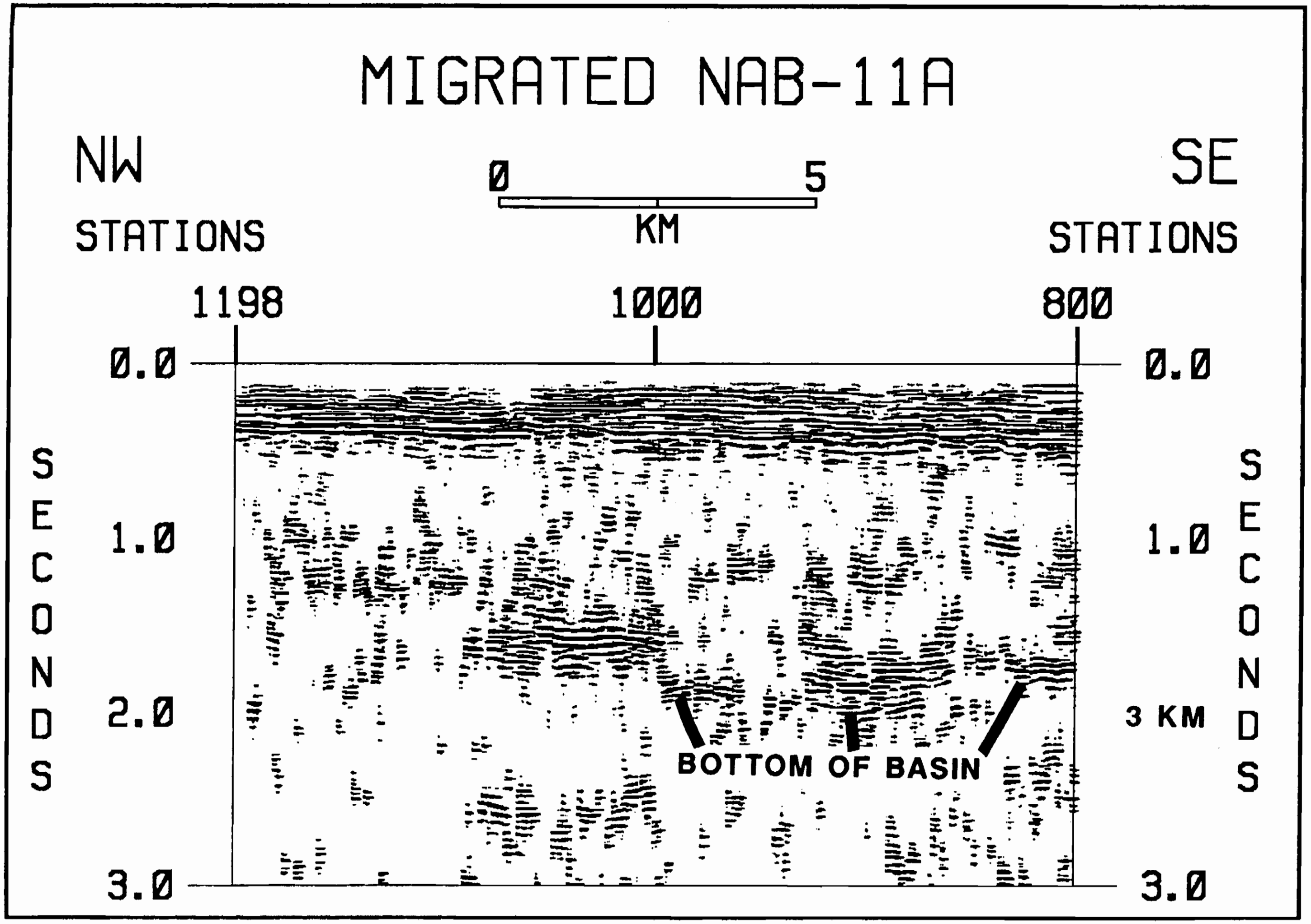


Figure 11. Total depth of the Taylorsville basin: The basin extends as deep as 2 seconds or approximately 3 km.

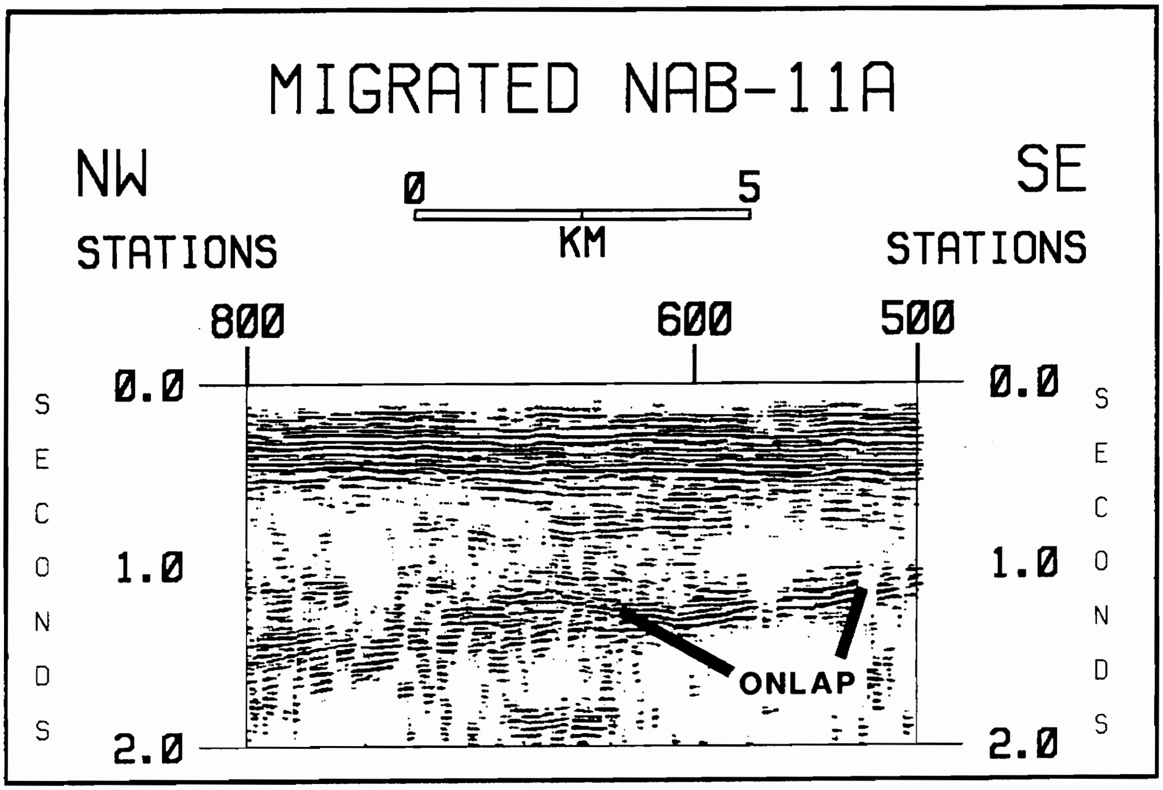


Figure 12. Onlapping within the Taylorsville basin: Overall, the strata within the basin are non-reflective except locally where they appear to be onlapping the bottom of the basin.

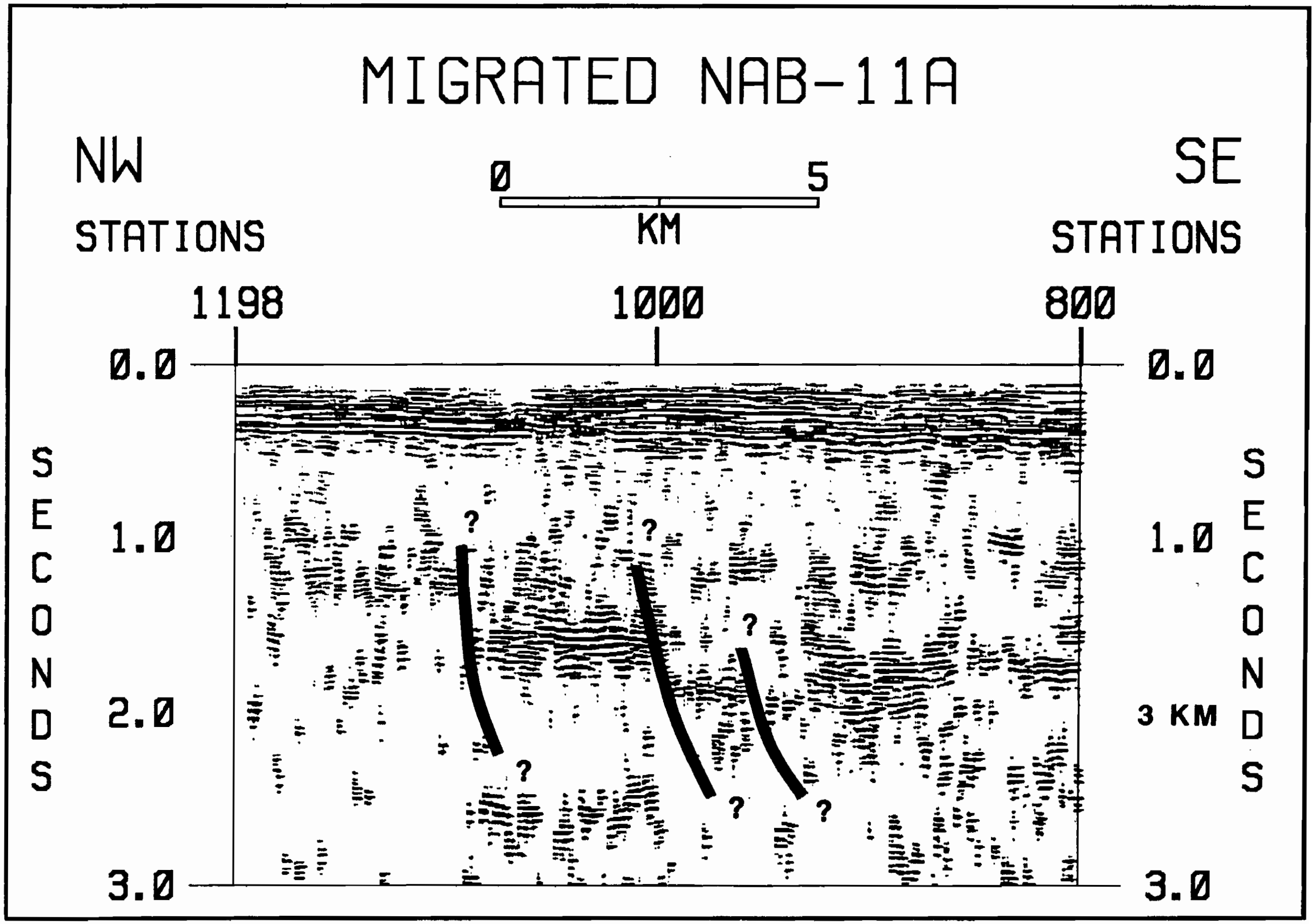
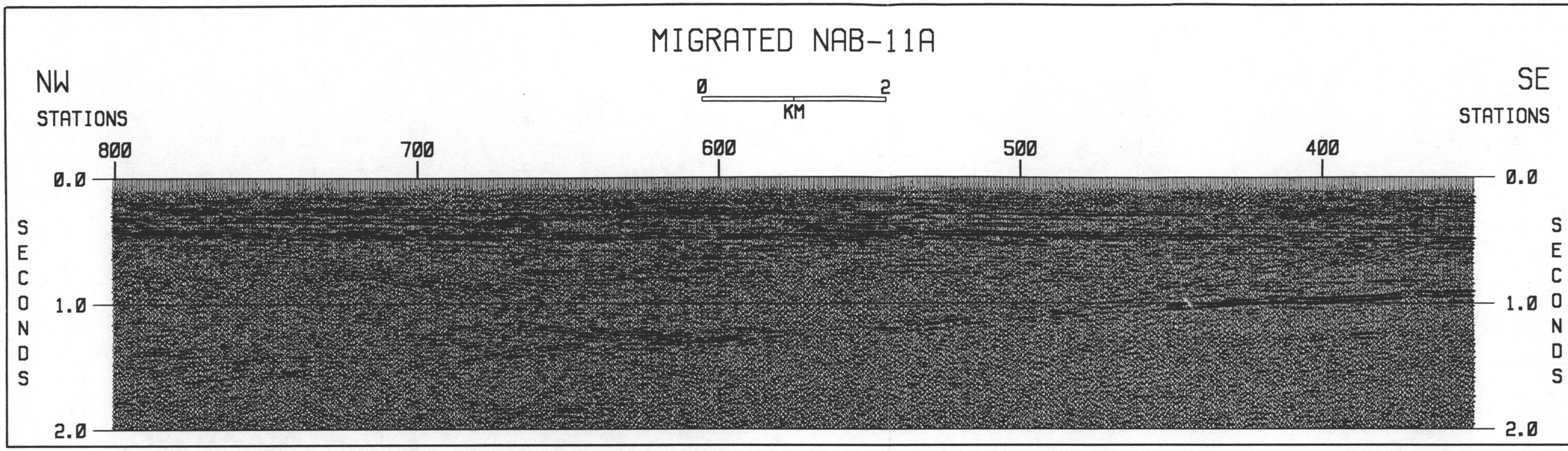


Figure 13. **Normal faulting within the Taylorsville basin:** Normal faults, probably related to Mesozoic extension, are observed west of station 800.



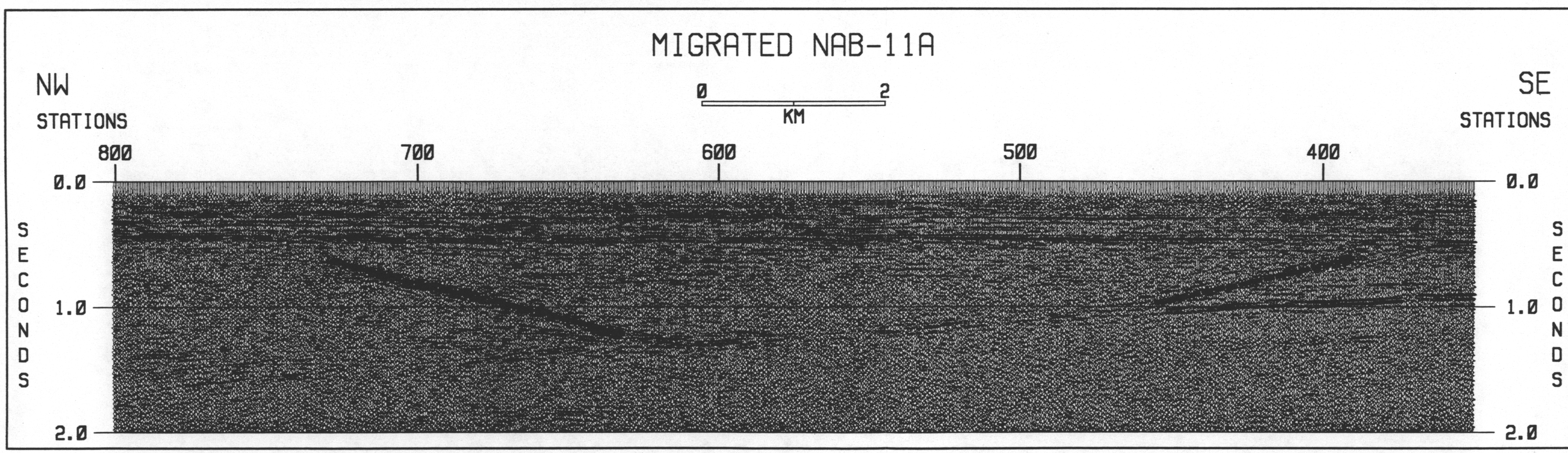


Figure 14. Dikes fed by the sill: Prominent crosscutting reflectors are interpreted to be dikes fed by the sill.

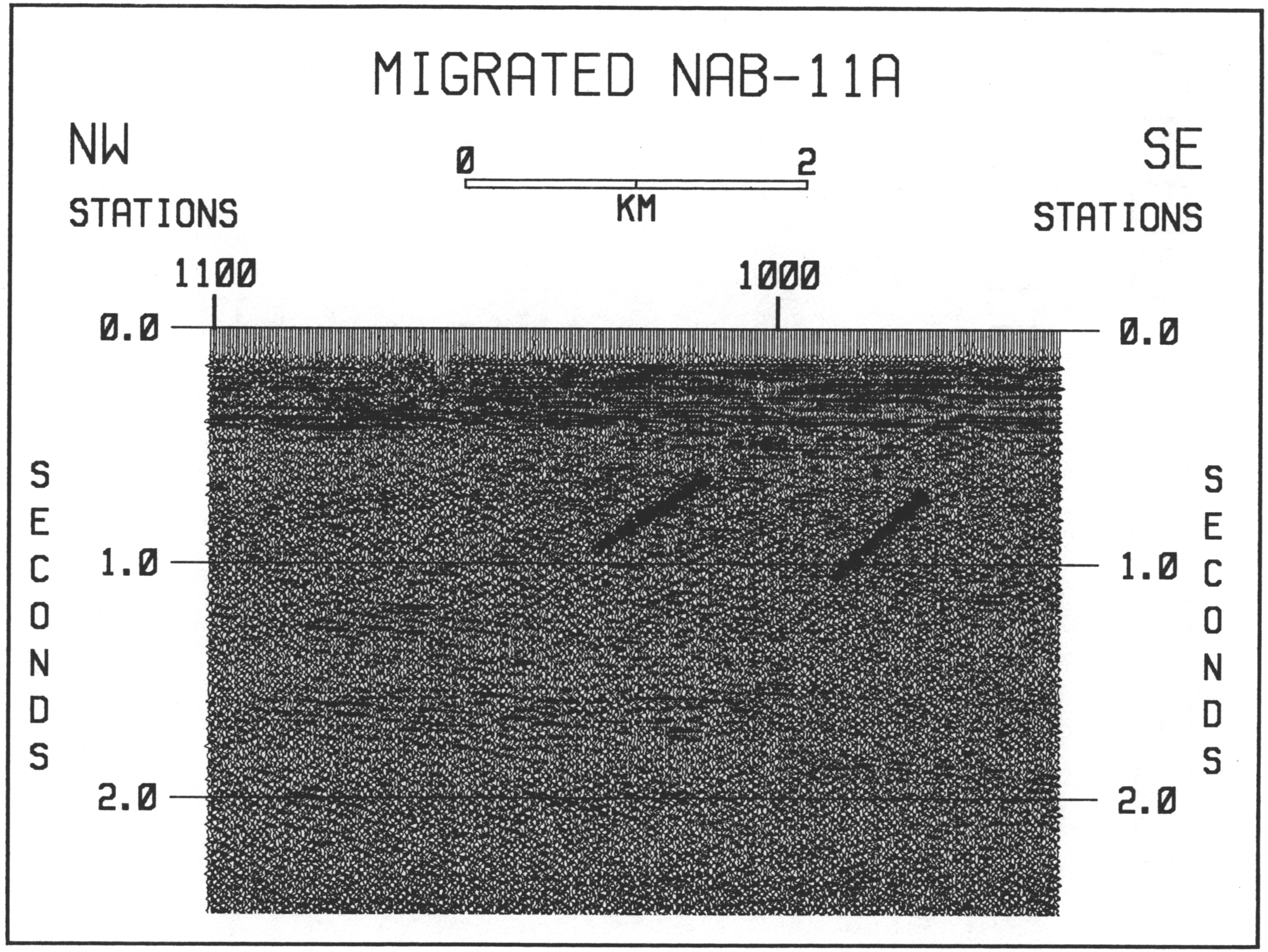


Figure 15. **Dikes in the west part of the basin:** Prominent crosscutting reflectors in the west part of the basin are interpreted to be dikes.

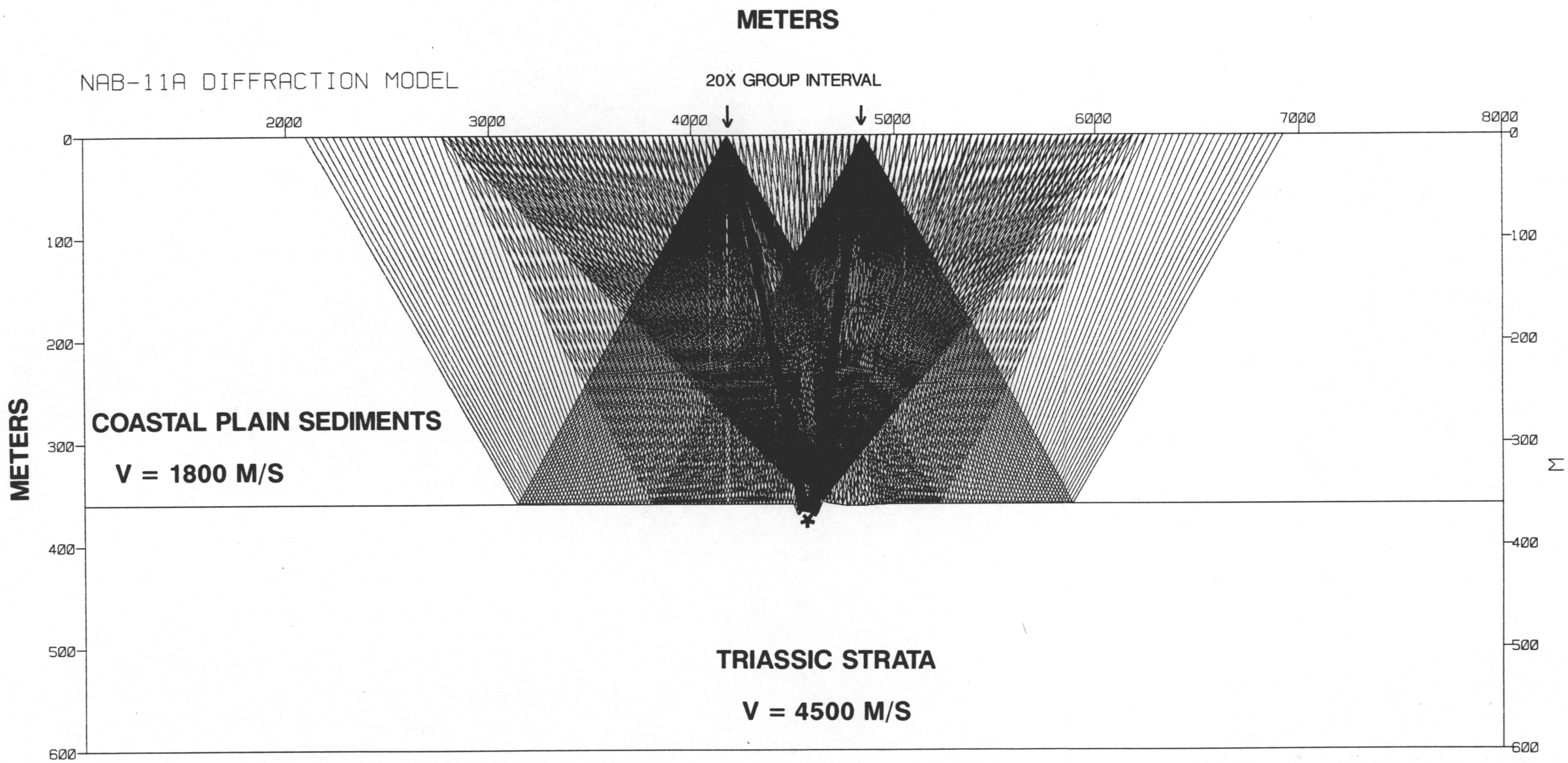


Figure 16. Raypath diagram: Synthetic model illustrating the diffractor (*) and ray path for 2 shots at 20 times the group interval.

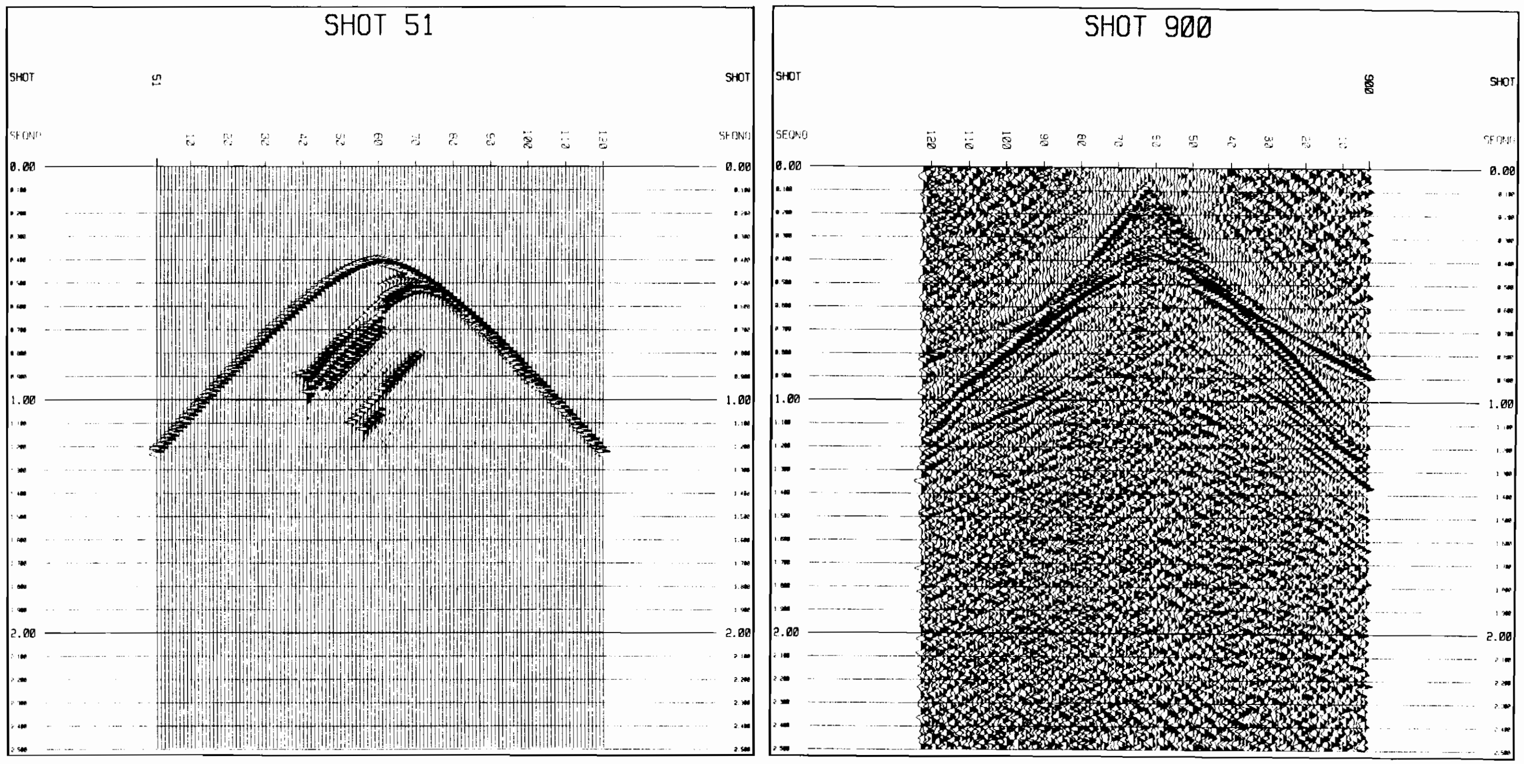


Figure 17. **Real and synthetic shots:** Comparison of real (right) and synthetic (left) shots.

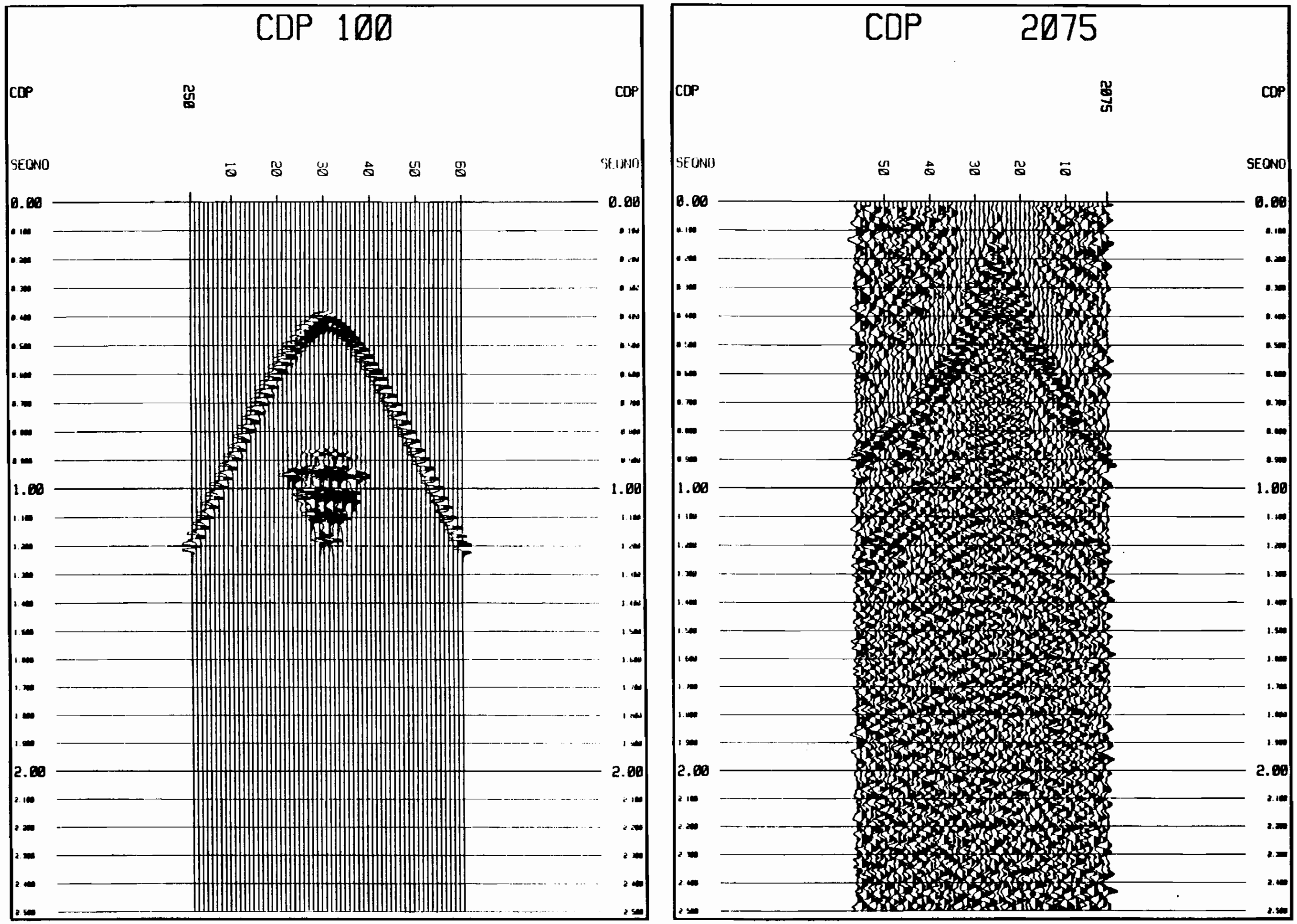


Figure 18. **Real and synthetic CDPs:** Comparison of real (right) and synthetic (left) CDPs.

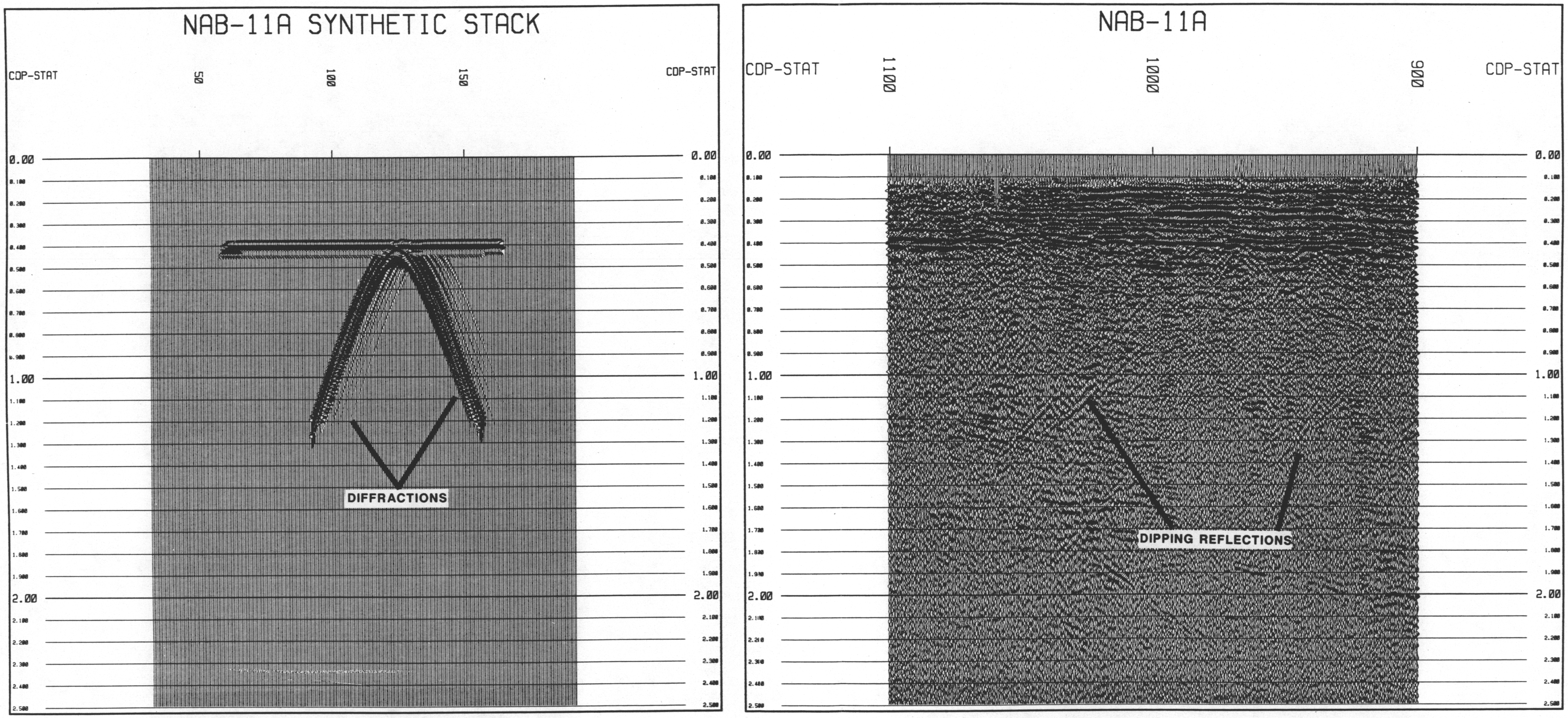


Figure 19. Real and synthetic stacked data: The dip of the reflections on a stack of the synthetic data are significantly steeper than those on a stack of the real data.

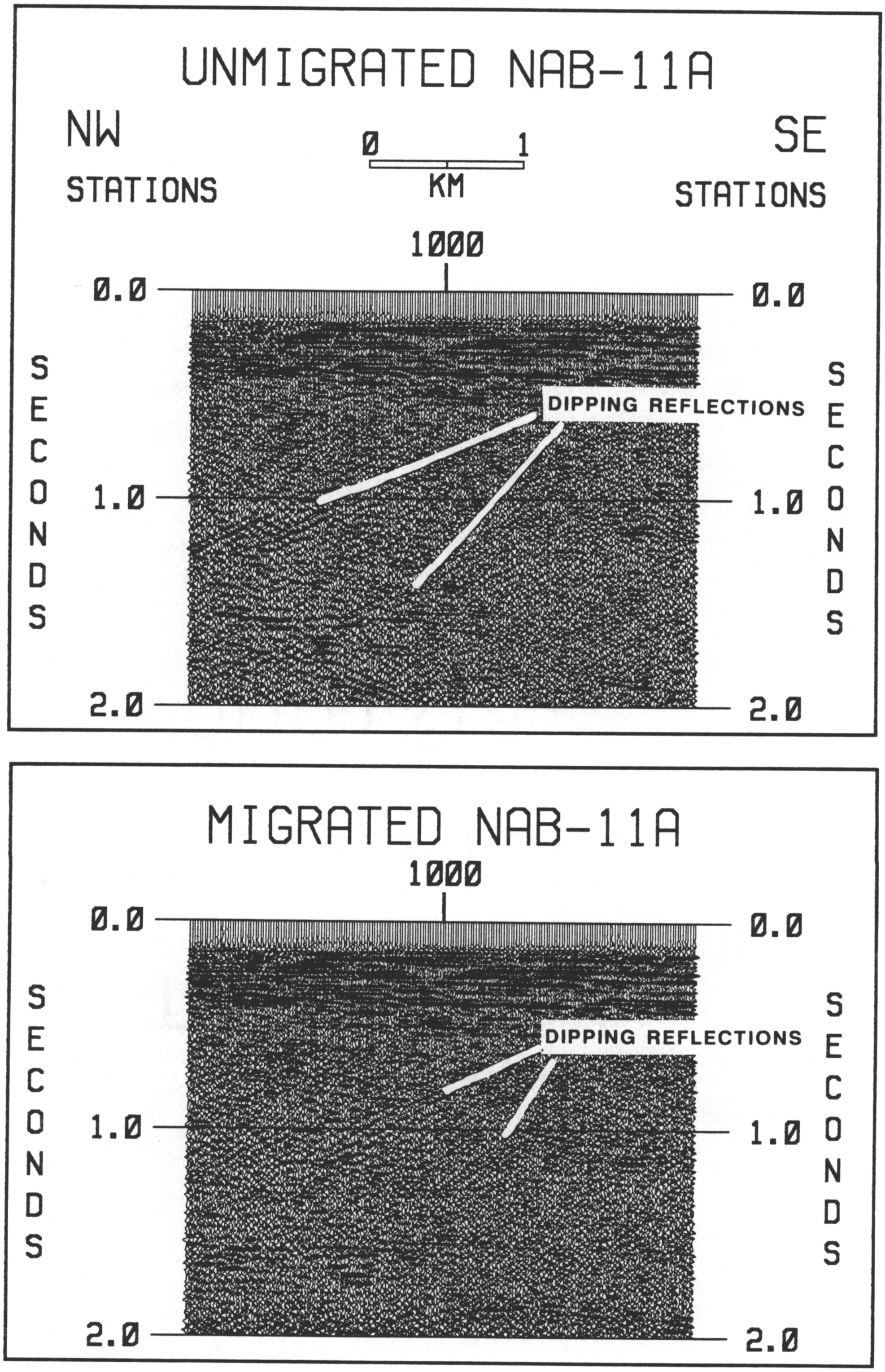


Figure 20. Comparison of the unmigrated and migrated data: Migration does not remove the dipping reflectors but steepens them, compresses them and moves them up in time.

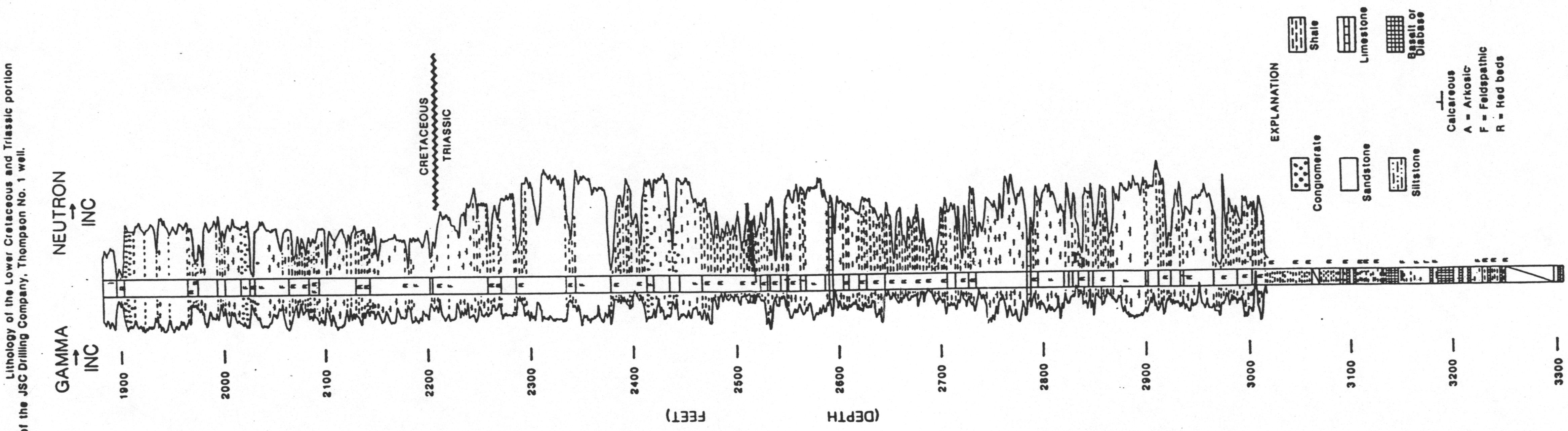


Figure 21. Log data within the Taylorsville basin: Well log data confirm the existence of basaltic material within the Taylorsville basin.

The Coastal Plain

The coastal plain thickens from 400 ms (~ 350 m) in the west to 550 ms (~ 500 m) in the east on line NAB-11A (Figure 22). In addition, the lower part of the sedimentary package loses its reflectivity to the east (Figure 22). The lack of reflectivity in the Lower Cretaceous sediments, which is most obvious on line CF-1 (Figure 23), is attributed to a lack of density contrasts and perhaps a lack of stratification. Here, the coastal plain sediments vary in thickness from 1.7 seconds (~ 1800 m) in the west to 1.85 seconds (~ 2000 m) toward the east. The estimated thicknesses of the coastal plain sediments along both lines are consistent with a depth to basement map for the study area (Benson, 1984). The poorly defined basement reflection (Figure 23) is attributed to two factors: the lack of an abrupt density and velocity contrast between the basement and the overlying coastal plain sediments and the effect of the deconvolution filter, which might be degrading the data. Because the predictive deconvolution operator is removing this feature, it is possible that the feature is a multiple and that it does not represent a real reflection. This also is a reasonable interpretation; however, the lack of a prominent basement reflection is supported by nearby unpublished log data (Figure 24), which suggest that there is a lower acoustical zone with a gradual increase in velocity near the disconformity.

A steep, southeasterly dipping, reverse fault has been identified within the coastal plain sediments between station 1000 and 1050 on line NAB-11A (Figure 25). The dip of this fault is in the opposite direction of other faults observed within the coastal plain (Mixon and Newell, 1977). The fault appears to penetrate basement and perhaps was activated by rotation during postrift cooling and subsidence.

Gravity Modelling

There is a dominant reflection package between stations 600 and 700 at 2 to 4 seconds on line NAB-11A. A velocity study at station 675 (Figure 26) indicates that these reflections are real and not multiples generated from the postrift unconformity above. As a result, gravity modelling

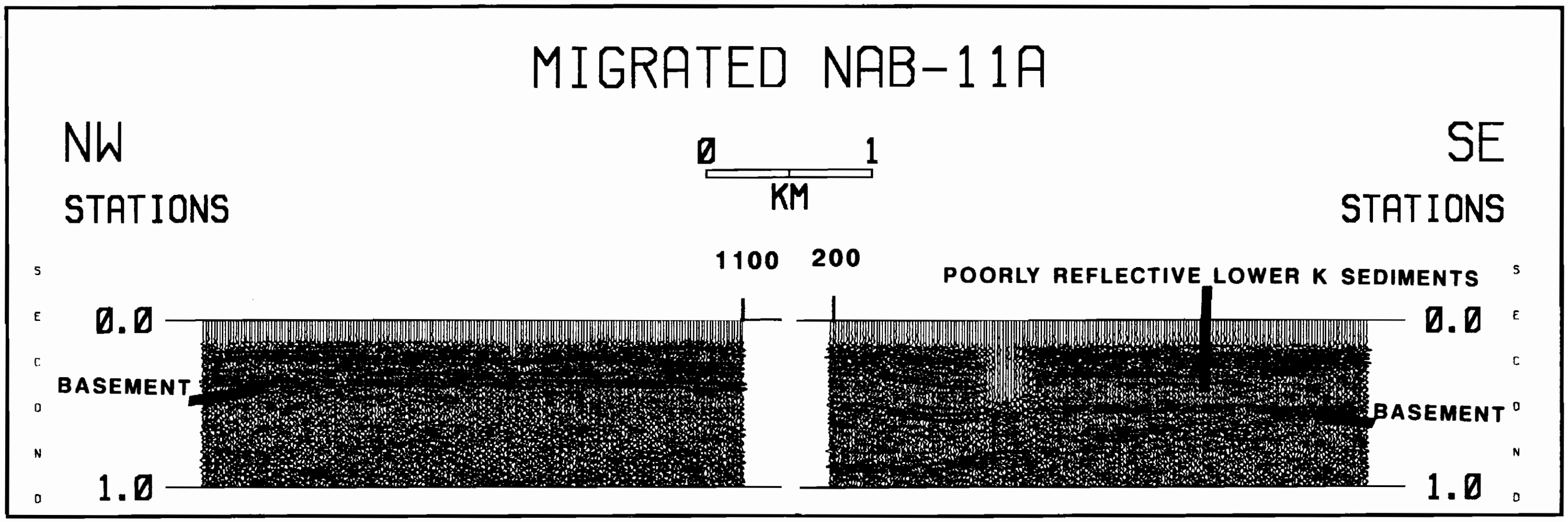


Figure 22. Increase in thickness of the coastal plain sediments: The coastal plain sediments thicken on line NAB-11A from 400 ms to 550 ms or approximately 350 m to 500 m, respectively.

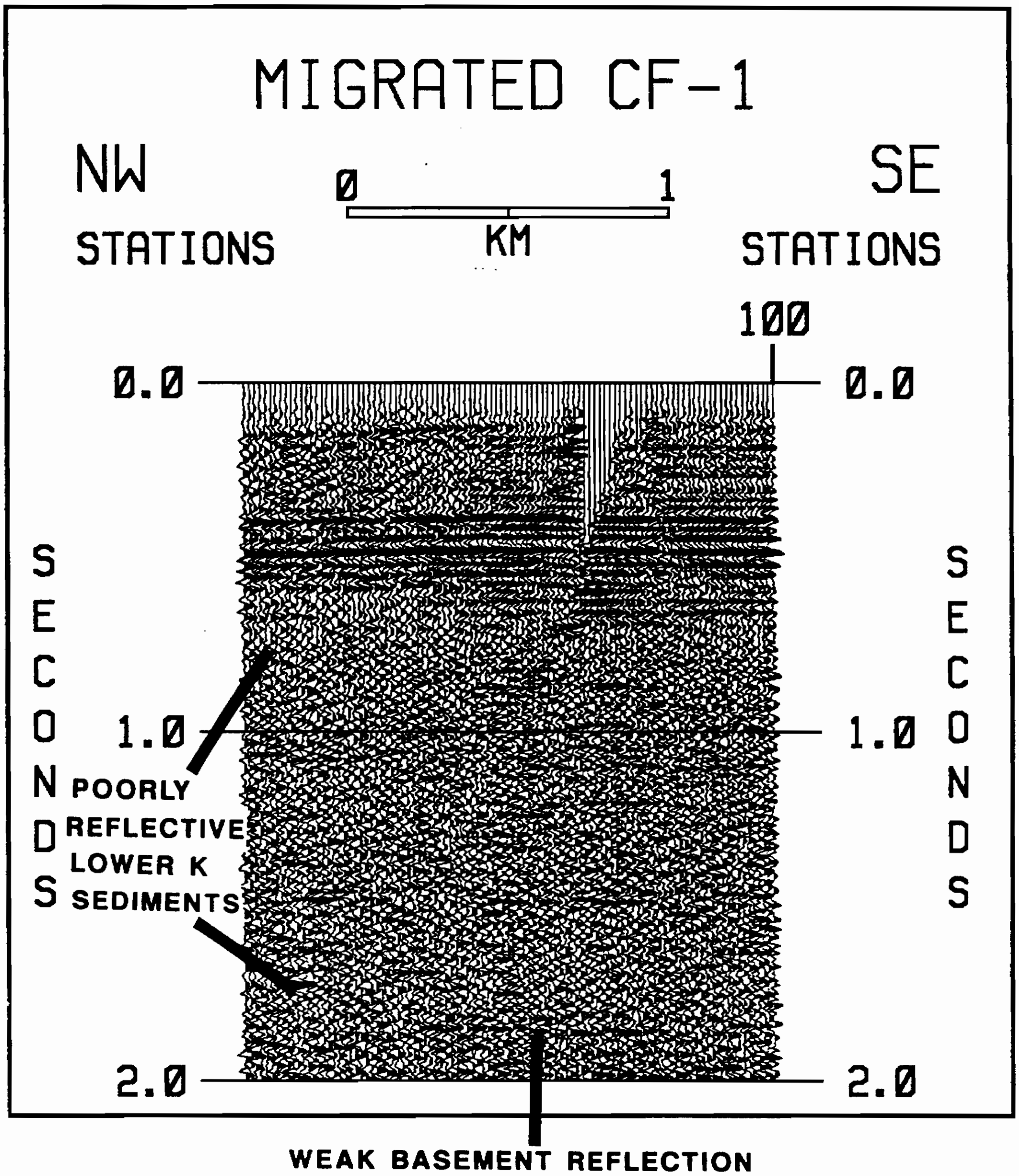


Figure 23. Lack of reflectivity in the Lower Cretaceous sediments: The lack of reflectivity in the Lower Cretaceous sediments is obvious on line CF-1. Notice that the basement reflector (?) is weakly defined here.

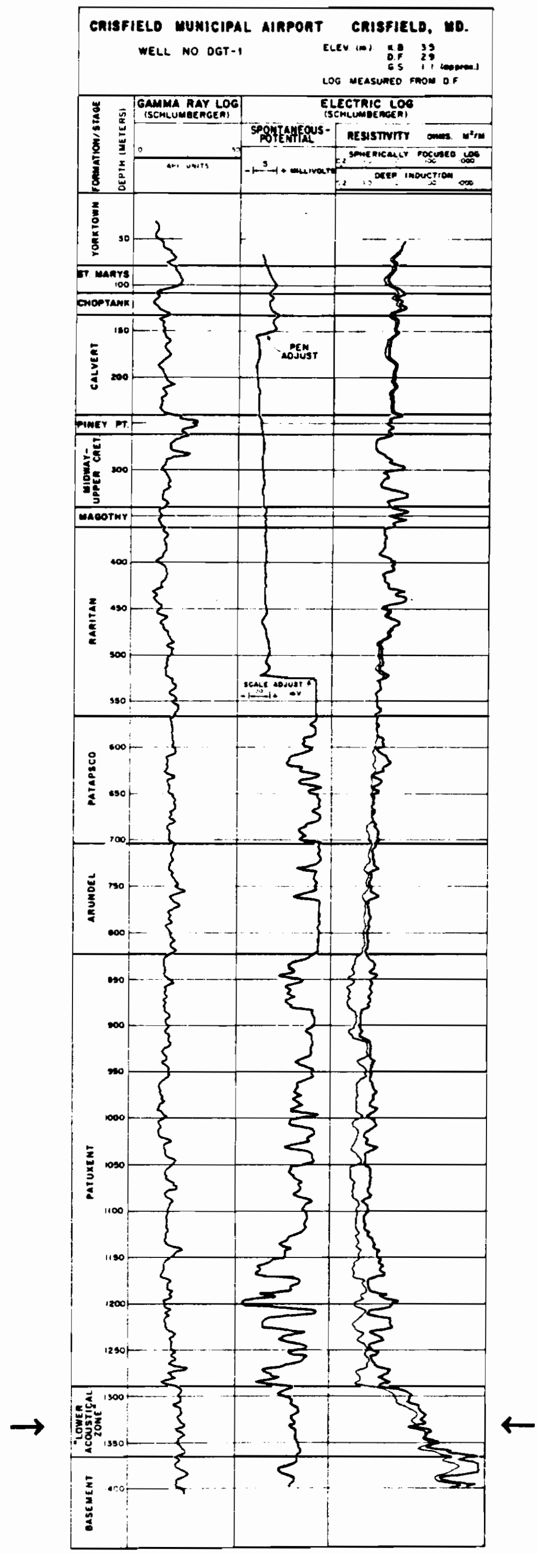


Figure 24. Log data near line CF-1: A well log near line CF-1 indicates that there is a low acoustical zone (arrows) at the disconformity.

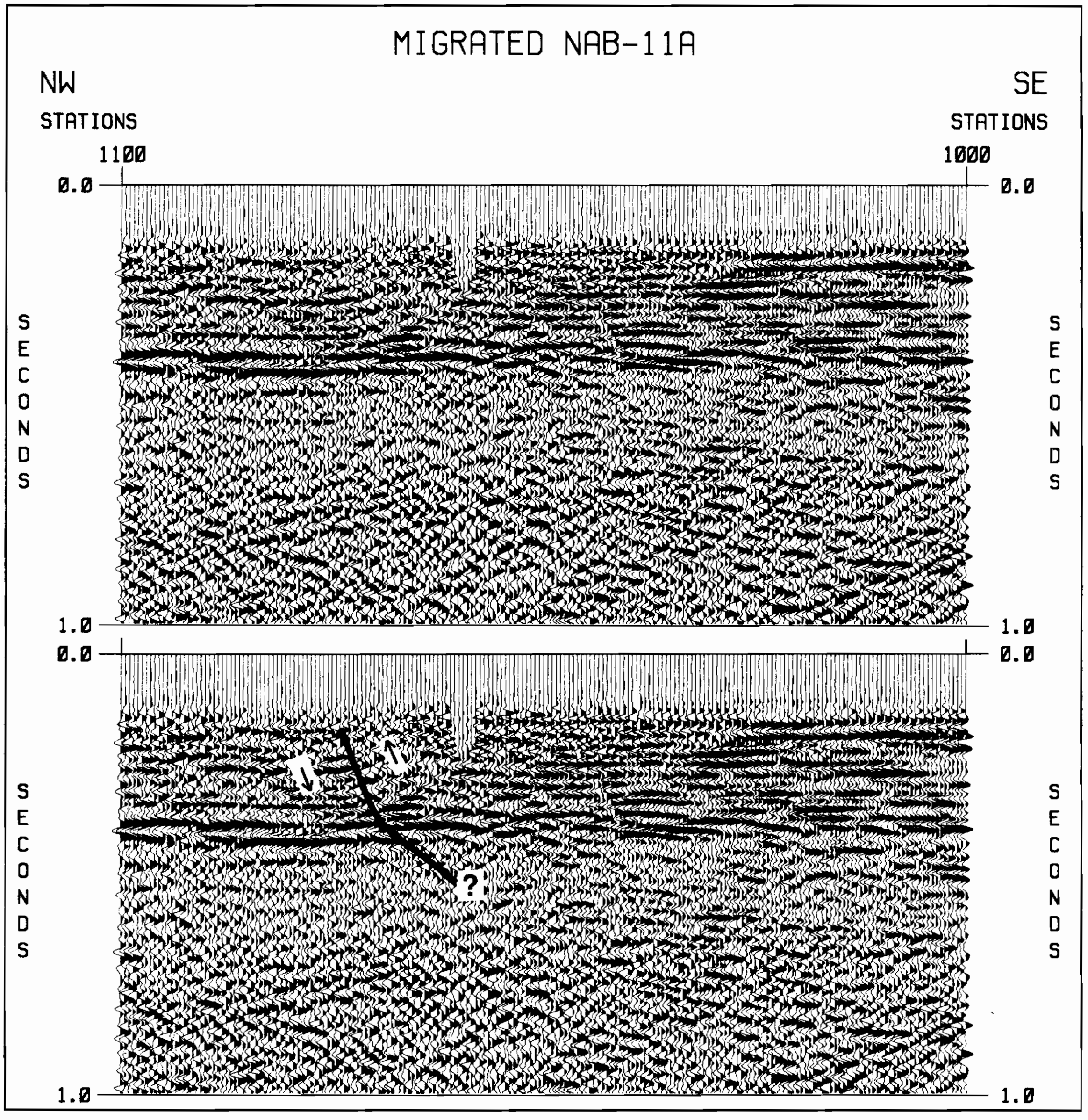


Figure 25. Reverse faulting in the coastal plain sediments: A reverse fault identified on the west part of line NAB-11A dips in the opposite direction as other reverse faults observed within the coastal plain.

was performed in order to determine whether the reflections might be low density strata within the Taylorsville basin. In addition, modelling was carried out in order to examine the interpretation of a vertically dipping anomalous mass that extends to the Moho. The Bouguer anomaly profile over line NAB-11A is in the Appendix.

The Bouguer anomaly derived from the geological model proposed in this study almost exactly matches the observed Bouguer anomaly at line NAB-11A (Figure 27). The assumed rock types, densities and density contrasts used to calculate the Bouguer anomaly are summarized in Table 3.

Results from gravity modelling indicate that the strong basal reflection must approximately mark the bottom of the basin in order to reproduce the observed Bouguer anomaly. If the basin was as deep as the reflection package previously described in this section, the Bouguer anomaly would have much higher negative values. The only way to reduce the amplitude of such an anomaly would be to use an unreasonably small density contrast (-0.03 g/cm^3) for the basin. Furthermore, interval velocities in this area (Fig. 26) approximate crystalline rock velocities. No other interpretation for the reflection package is offered in this paper other than the possibility that it represents a strong, local foliation within the crystalline basement rocks.

Gravity modelling also suggests that the anomalous mass producing the gravity and magnetic anomalies east of the Taylorsville basin extends to the Moho and that the mass is (near) vertical. Two assumptions were made with regard to modelling the vertical mass: the mass is not all diabase but becomes more mafic with depth and the mass is a dike swarm, therefore, there would be lower density crustal material within the swarm that would decrease the average density contrast. Furthermore, decreasing density contrasts with depth represent the increasing average density of the crust. A second deep, mafic mass had to be placed on the northwest side of the model in order to reproduce the gravity field in that area. Although this interpretation extends beyond line NAB-11A, it was extrapolated along tectonic strike with another non-reflective zone on line I-64 near station 2000 (Figs. 7, 8 and 9) that also was interpreted by Çoruh and others (1988) to be a Mesozoic dike swarm. A similar interpretation west of line NAB-11A merits credibility because it corresponds to the northern extension of the same gravity and magnetic anomalies crossed by line I-64 to the

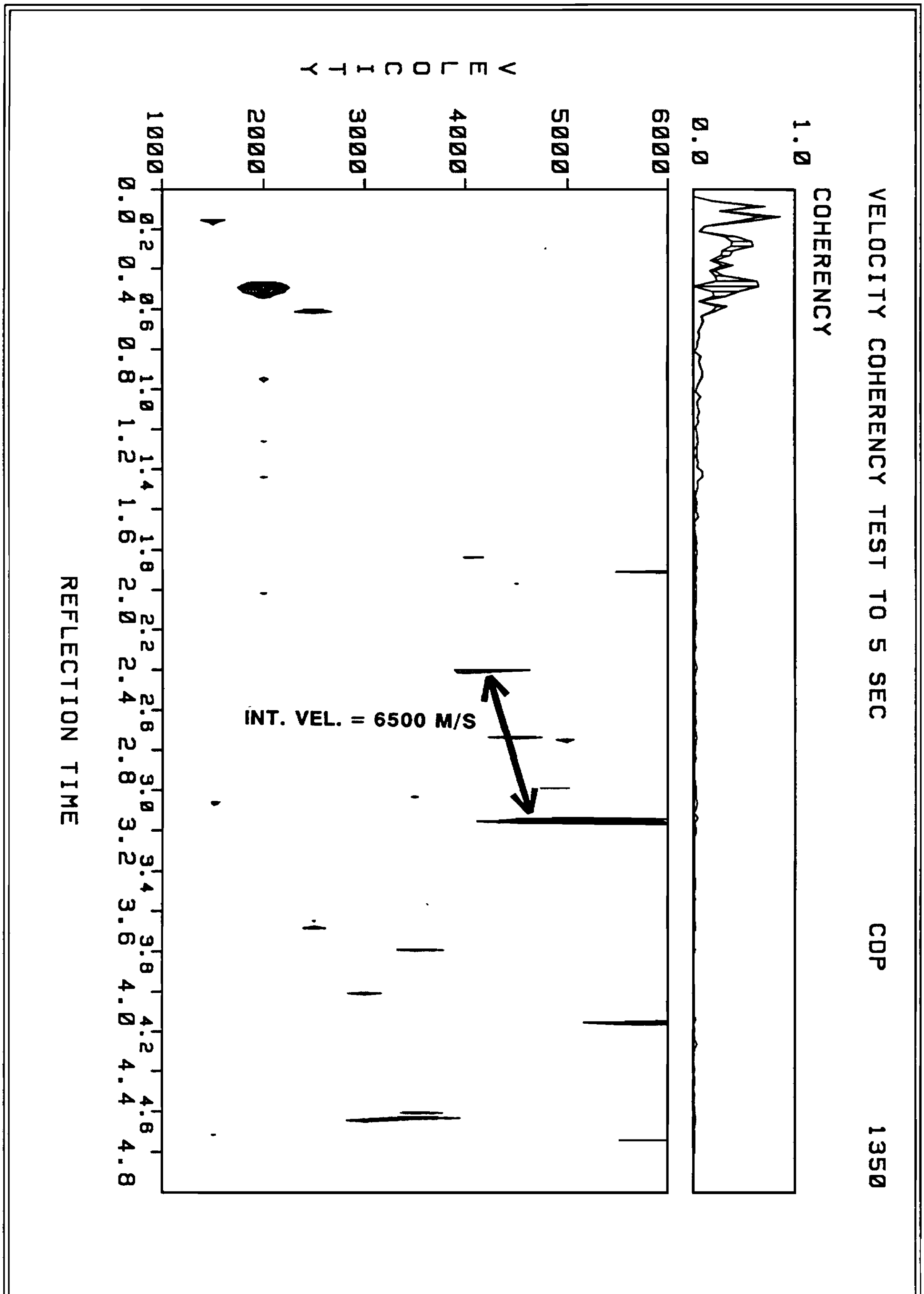


Figure 26. Velocity study on line NAB-11A: A velocity study near station 675 suggests that reflections seen between 2.4 and 3.2 seconds are not multiples. Multiple velocities would remain constant with depth.

Table 3. Rock types and rock densities assumed for gravity modelling

Rock Type	Avg. Dens. Cont.	Approx. Dens.
Unconsolidated coastal plain sediments	-0.5	2.17 g/cm^3
Triassic strata	-0.1	2.63 g/cm^3
Mafic mass		
upper crust	0.2	2.93 g/cm^3
middle crust	0.1	2.95 g/cm^3
lower crust	0.01	3.01 g/cm^3

south. Orientations other than vertical resulted in moderate to large deviations in shape from the observed anomaly (Figure 28). Furthermore, a less deep mass requires an unreasonably high density contrast (0.45 g/cm^3) to produce an anomaly that matches the amplitude of the observed anomaly (Fig. 28). This high density contrast is equivalent to a rock density of approximately 3.18 g/cm^3. This suggests that the anomalous source could be a Mesozoic dike swarm as proposed by Çoruh and others (1988) or possibly an ancient magma chamber that, on the basis of the reflections below the basin between stations 110 to 200 (Figure 29), collapsed upon cooling.

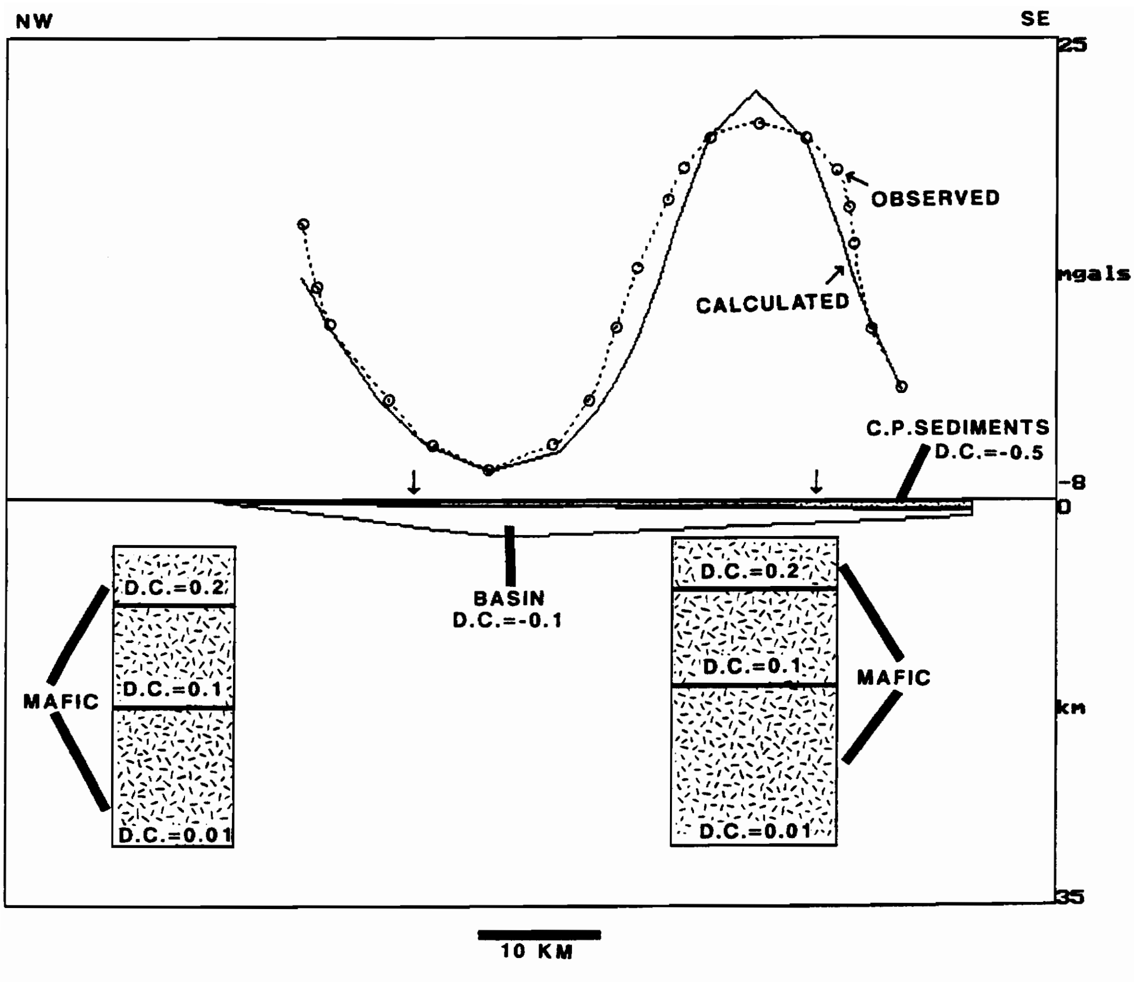


Figure 27. **Gravity model 1:** A model based on the features seen on line NAB-11A almost exactly reproduces the gravity field in this area. Arrows indicate the actual position and lateral extent of line NAB-11A. Density contrast (D.C.) in g/cm^3.

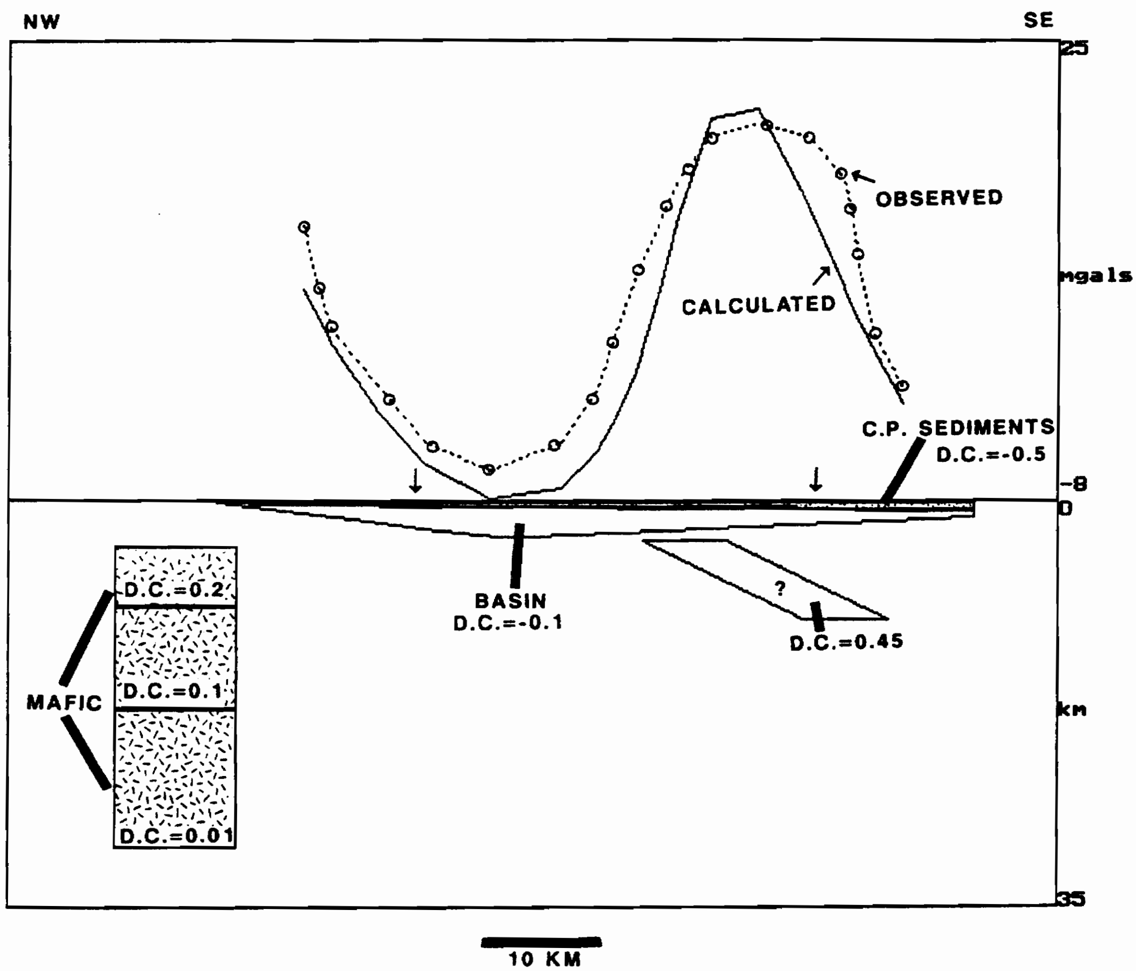


Figure 28. Gravity model 2: A model with a less deep mass of shallower dip does not reproduce the gravity field in this area. Note the loss of symmetry. Arrows indicate the actual position and lateral extent of line NAB-11A. Density contrast (D.C.) in g/cm^3.

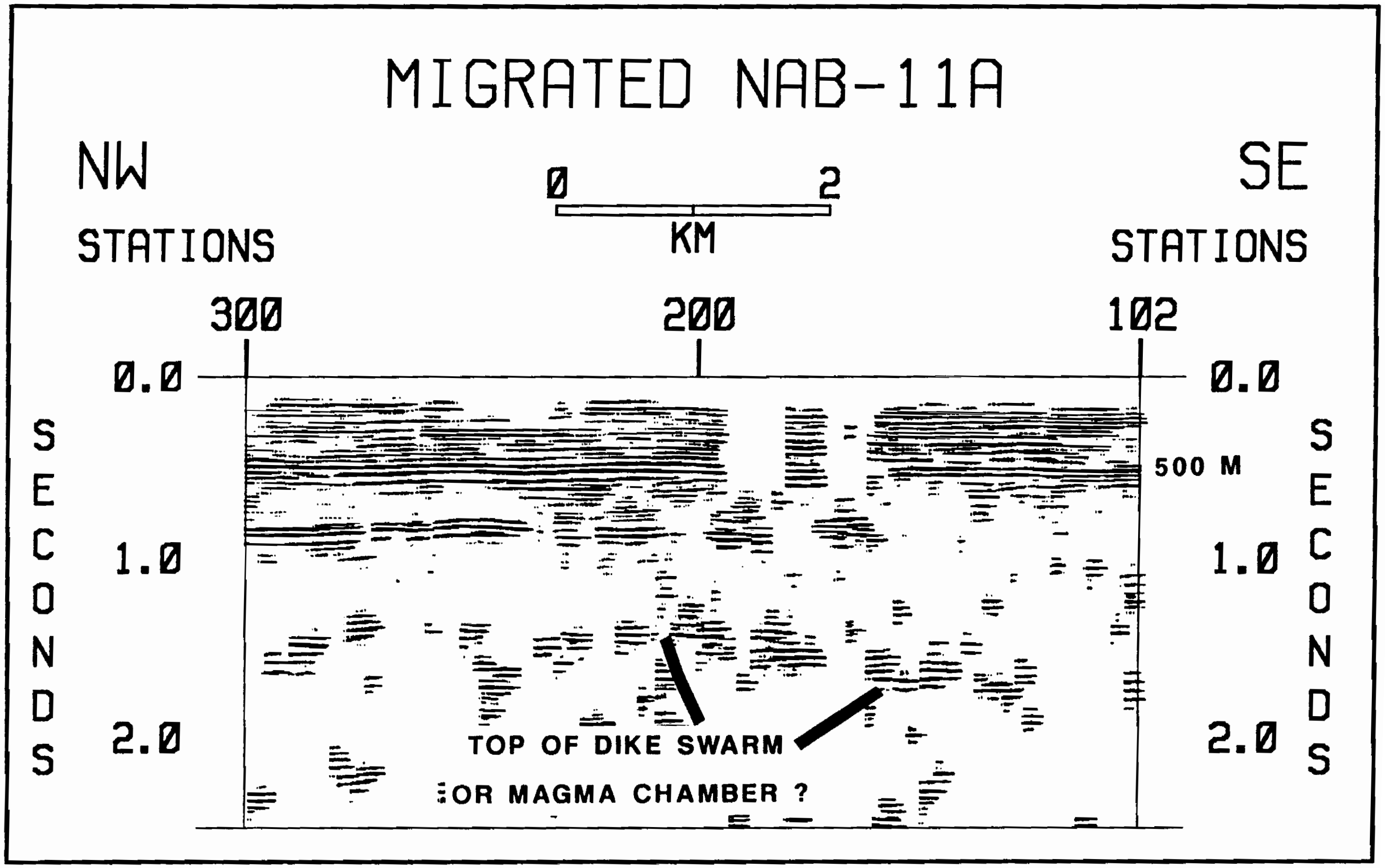


Figure 29. **Reflections corresponding to the potential field anomalies:** Reflections below the basin in the area of the potential field anomalies might represent the top of a dike swarm or the top of a collapsed magma chamber.

Conclusions

Several important results have been achieved from this study. Lower Cretaceous fluvial sediments are considerably less reflective than the overlying marine sequence. This observation is most obvious toward the east, particularly on line CF-1. Reverse faulting, which might be related to movement within the basement, is observed in at least one location on line NAB-11A. Curiously, the fault dips to the southeast. This is the opposite direction of other reverse faults observed within the coastal plain.

The thickness of the Taylorsville basin strata is constrained well by seismic reflection data and gravity modelling. Results indicate that the basin is approximately 3 km deep. The strata within the basin appear to be poorly reflective except where they locally onlap the bottom of the basin, which is marked by a prominent reflection that is interpreted to be a diabase sill associated with Jurassic magmatism. In addition, the basin appears to be intruded by moderately dipping dikes that were fed by the sill. The occurrence of basaltic material within the basin is confirmed by well log data.

Probably the most important result of this study is the tectonic implications of prominent, arcuate potential field anomalies and their relationships to lateral changes in reflectivity of crystalline basement observed on the east side of line NAB-11A. Gravity modelling confirms the likelihood of a near-vertical, anomalous, mafic mass that extends to the Moho. This observation is supported by the loss of reflection continuity in this area. A similar observation was made by Çoruh and others (1988) who proposed that this feature is a dike swarm associated with Mesozoic rifting. It is proposed here that this body also could be an ancient Mesozoic magma chamber that collapsed during cooling after the Atlantic margin passed into the drift sequence.

Further Research

Further research in this area requires more seismic data, particularly over the potential field anomalies. Furthermore, 2-dimensional or 3-dimensional potential field modelling must be performed in order to constrain geological models inferred by reflection seismic data. Potential field data are ambiguous; however, any geological model must agree with the observed field. Although agreement does not constitute endorsement of a geological model, lack of agreement between calculated and observed values is sufficient evidence to discredit a model.

Without question, the most necessary contribution to our understanding of the Taylorsville basin and the Atlantic margin in this area would be core information. More cores would provide the petrologic, stratigraphic and paleontologic information needed to discern the tectonic evolution of this area. In addition, core information could be extended to well log data in order to extrapolate laterally the geological database. Deeper boreholes could provide resistivity and sonic information that would assist both in lithologic interpretation and in seismic processing and interpretation.

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Appendix A. Gravity Profile along Line NAB-11A

O B S E R V E D   D A T A

Entry Number	Station Name	Horizontal Location kilometers	Bouguer Gravity mgals
1	1	0	12
2	2	.8	8
3	3	2.42	4
4	4	6.44	0
5	5	10.46	-4
6	6	16.1	-6
7	7	22.14	-4
8	8	25.36	0
9	9	26.97	4
10	10	28.58	8
11	11	30.59	12
12	12	32.2	15
13	13	35.01	18
14	14	39.1	19
15	15	43.55	18
16	16	46.69	15
17	17	47.5	12
18	18	48.1	8
19	19	49.1	4
20	20	51.9	0

Vita

Phillip A. Pappano Jr. was born 30 March 1965 in Trenton, NJ. In the fall of 1983, he enrolled at Rider College in Lawrenceville, NJ. He completely financed his college education by working full time most of his undergraduate career. On 17 March 1989, he was married to Margaret M. Buckley in St. John's Catholic church. He finally earned his B.S. in geology in 1990. Approval of the degree included defending an undergraduate thesis entitled: A Gravimetric and Magnetic Investigation of the Subsurface Geology in the Hopewell-Pennington-Lambertville Area of the Central Newark Basin. In the fall of 1990, Phil enrolled in the M.S. program in the Department of Geological Sciences at V.P.I. & S.U. After earning his Master of Science degree, Phil will begin full-time employment as a Geophysicist with Amoco Production Co. in Houston, TX. Phil is a member of the American Association of Petroleum Geologists, American Geophysical Union, Geological Society of America and Society of Exploration Geophysicists.