TEC-7

GEOTHERMAL RESOURCES OF VIRGINIA AND WEST VIRGINIA

Geological and Geophysical Environment of Thermal Springs

By

Arthur L. Lange

With a

PETROGRAPHIC REPORT ON THREE ROCKS FROM HIGHLAND AND BATH COUNTIES, VIRGINIA

By

D. A. Andrews-Jones

PART II: Plates

April 16, 1973

CONTENTS

Part II: Plates

Frontispiece. Wading pool, Warm Springs, Virginia. The warm water bubbles up from gravels of the valley floor that overlie solution channels in the Beekmantown carbonate rocks below.

Plate A. Thermal pool on the grounds of The Homestead, Hot Springs, Virginia.

Plate B. Warm water springs (17°C, 63°F) 1½ kilometers south of Bridgewater, in the Shenandoah Valley.

Plate C. Felsitic sill-like intrusion (arrow) exposed in Hightown quarry, Highland County, Virginia. Youngest dated igneous rock in Eastern U.S. (47 million years). Sample A-1 described in Appendix III was taken from this site.

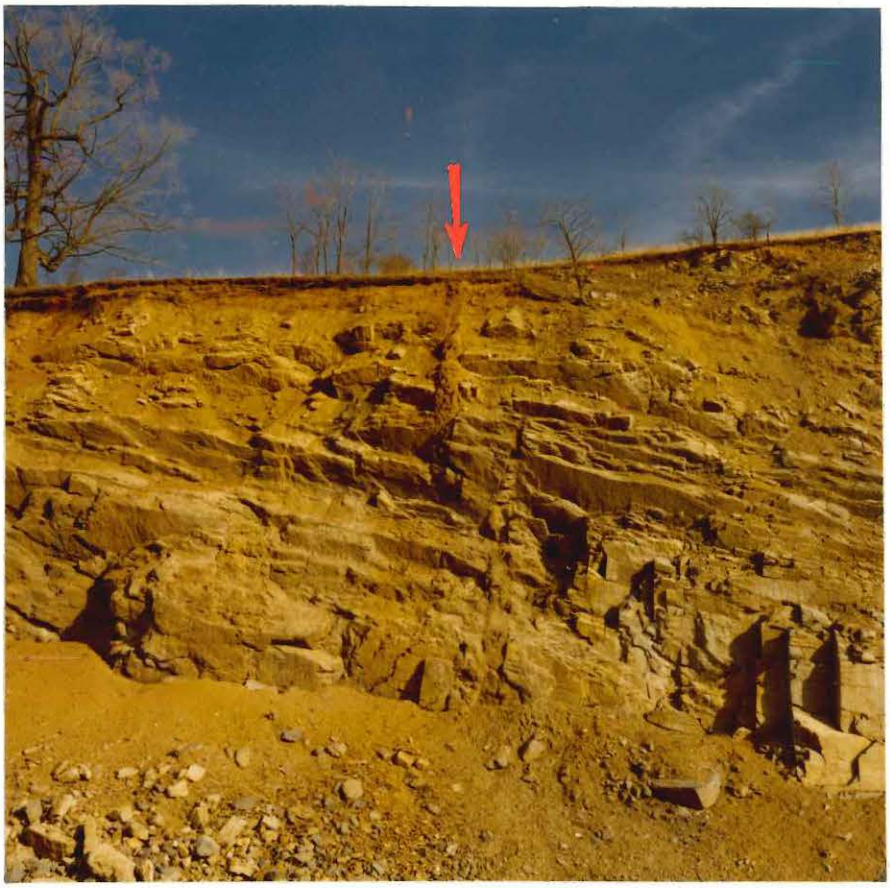


Plate D. Vertical felsitic dikes having strongly trachytic structure cut the body of Plate C, and are believed to be still younger. Sample A-2 from this exposure is described in Appendix III.

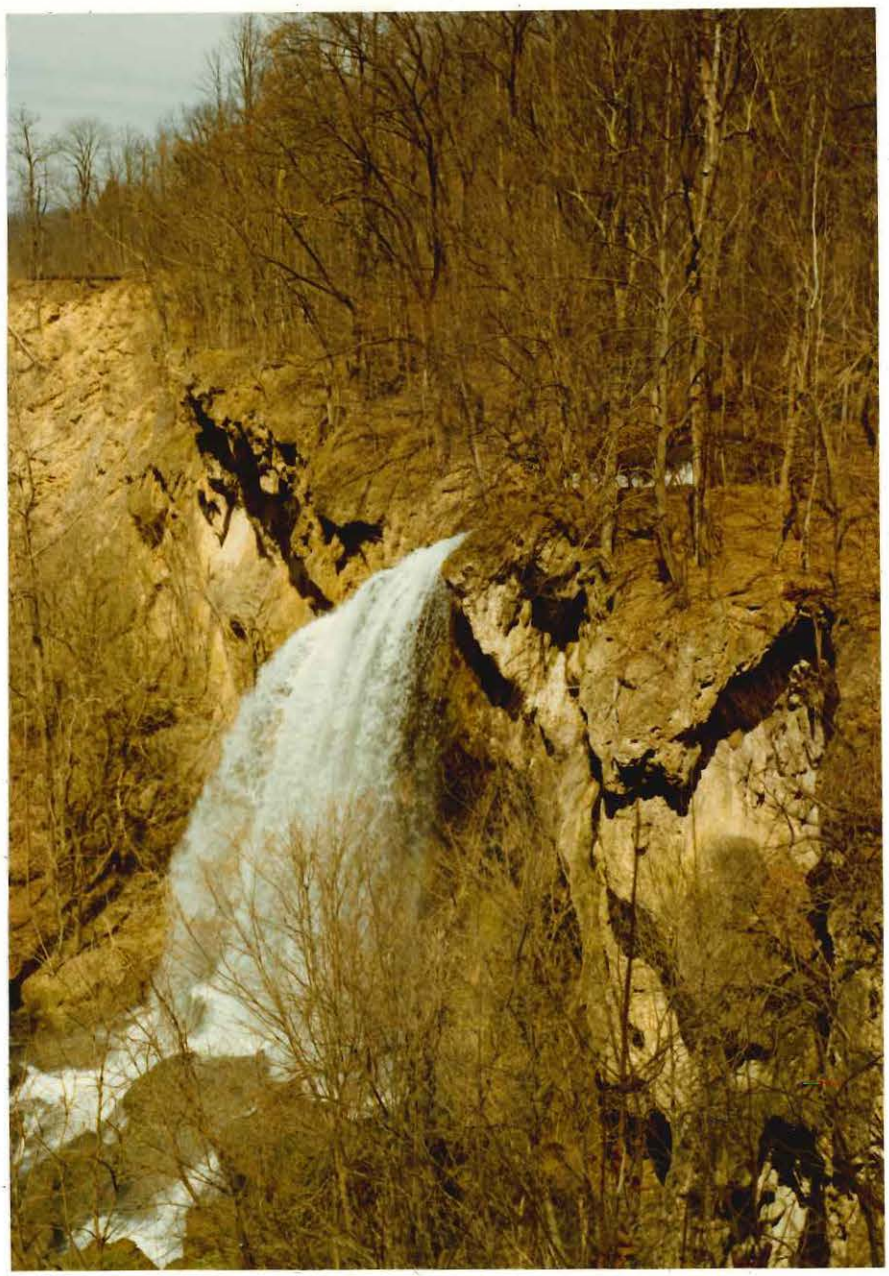
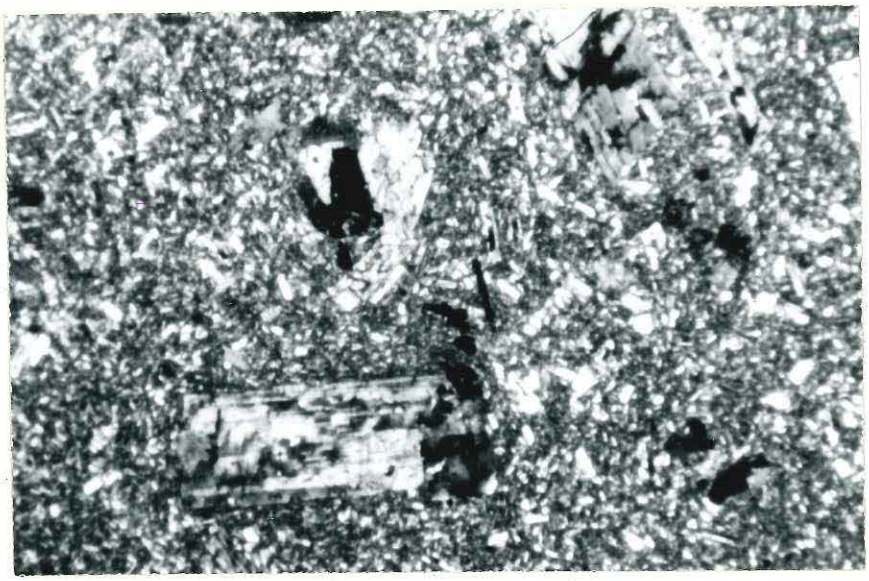
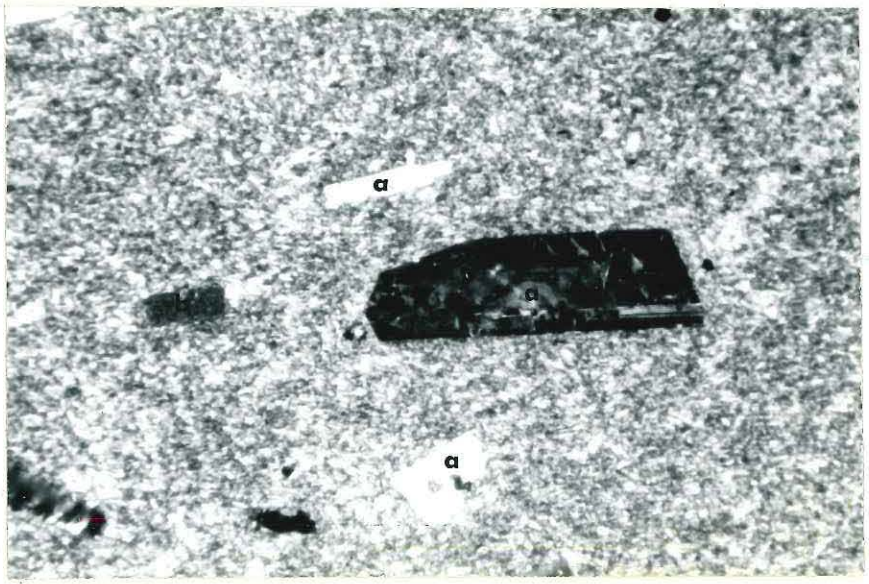


Plate E. Waters from Falling Springs have built up extensive travertine deposits that rim the south end of Warm Springs Valley. The flow discharges from Warm River Cave at 17°C (65°F); however, in the interior of the cave, water temperatures have been measured that exceed 37°C (100°F).

PLATE I: Textural Differences Between A1 & A2

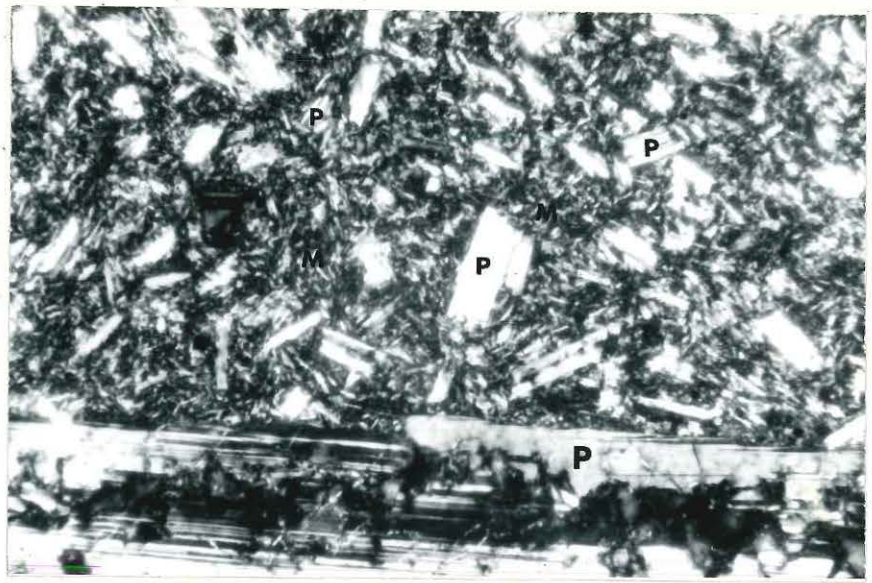


A1: Random orientation of mineral grains.
Phenocrysts of; albite light, biotite black.
XN, X12·5

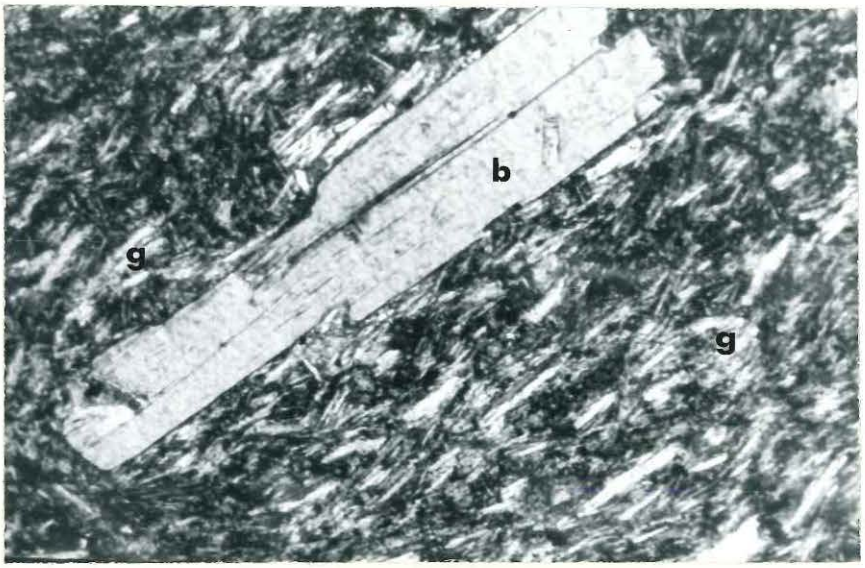


A2: Parallelism of mineral grains, zoning shown in albite phenocryst.
a = albite, b = biotite, XN, X12·5

PLATE II: Textural Comparison of A1 & A2 At High Power

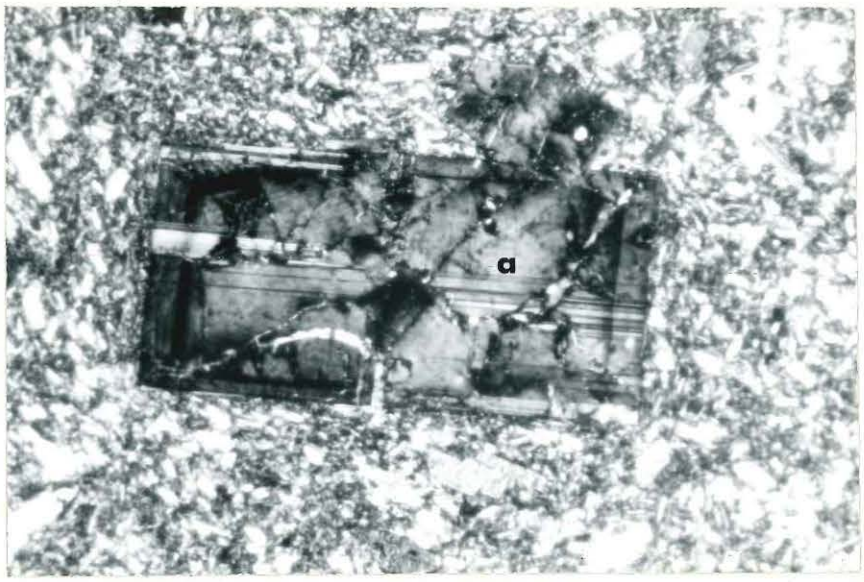


A1: Illustrates very variable size in phenocrysts, and interstitial character of feldspar microlites. P = phenocrysts (mainly albite) M = microlites. XN, X78·75

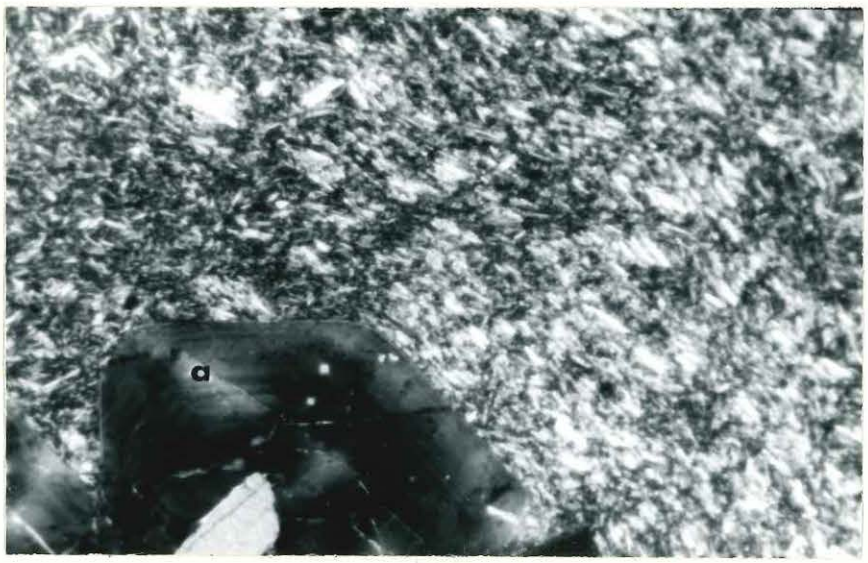


A2: Biotite phenocryst in a ground mass of strongly aligned albite laths.
b = biotite, g = ground mass. XN, X78·75

PLATE III: Multizoning & Strain In Albite Phenocrysts

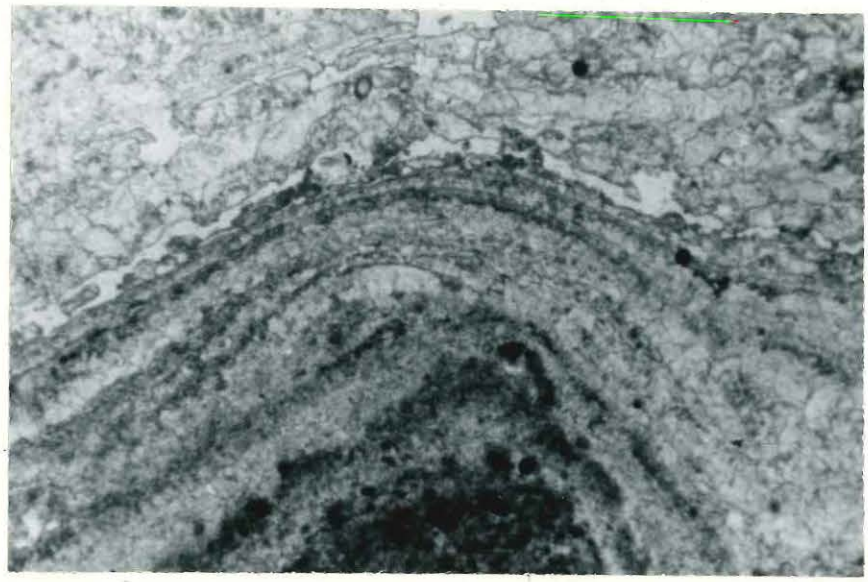


A1: Multizoned albite phenocryst (a) surrounded by randomly orientated smaller phenocrysts with interstitial microlites.
XN, X31·25



A2: Multizoned albite phenocryst (a) in a trachytic matrix of albite laths.
XN, X31·25

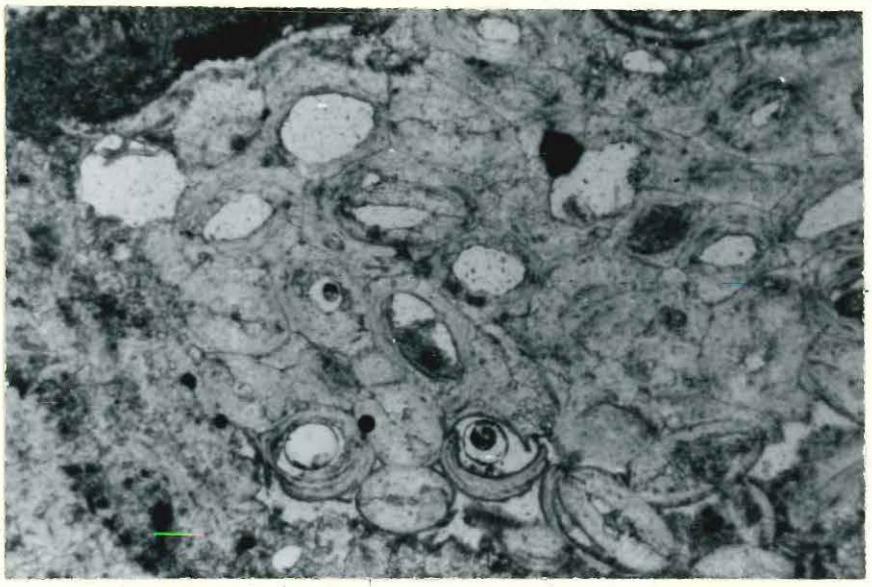
PLATE IV: Layering In Travertine



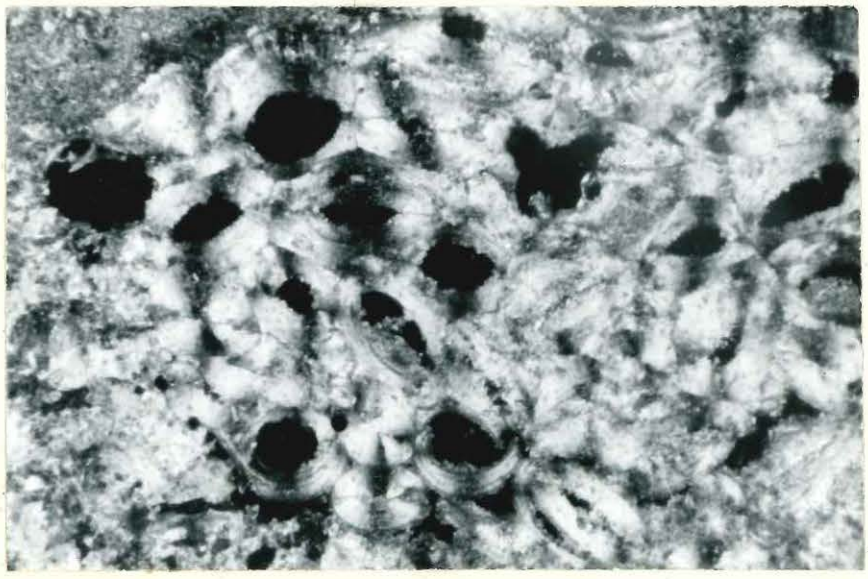
A3: Layering of calcium carbonate crystals in travertine, from very fine-grained (bottom center) to medium-grained (top) monochromatic light,
X31·25

A3: Same as above, but with crossed nicols.

PLATE V: Pisolitic Travertine



A3: Pisolitic aggregate in monochromatic light.
X31·25



A3: Same as above with crossed nicols.
Shows radiating fine carbonate grains within each ovoid.

GEOLOGIC

CROSS SECTION VIRGINIA

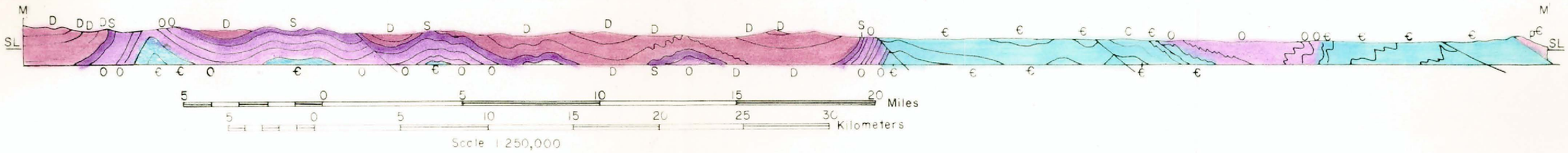


Plate 2A

TOPOGRAPHIC

CROSS SECTION - VIRGINIA

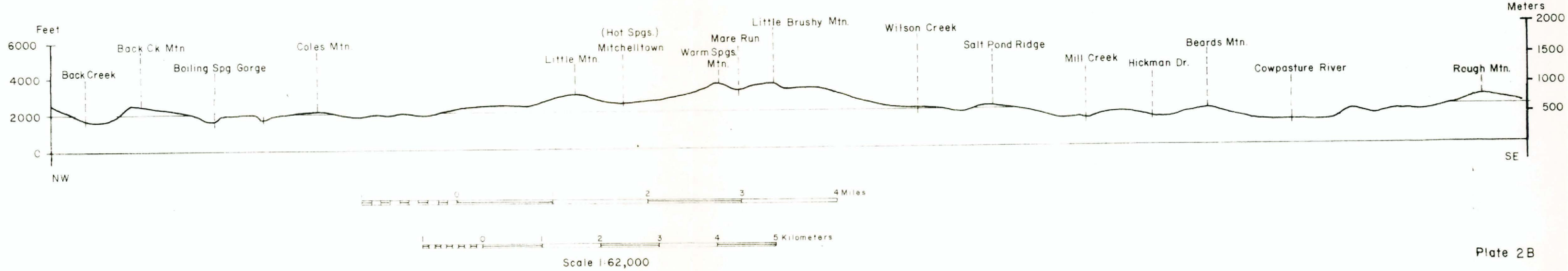
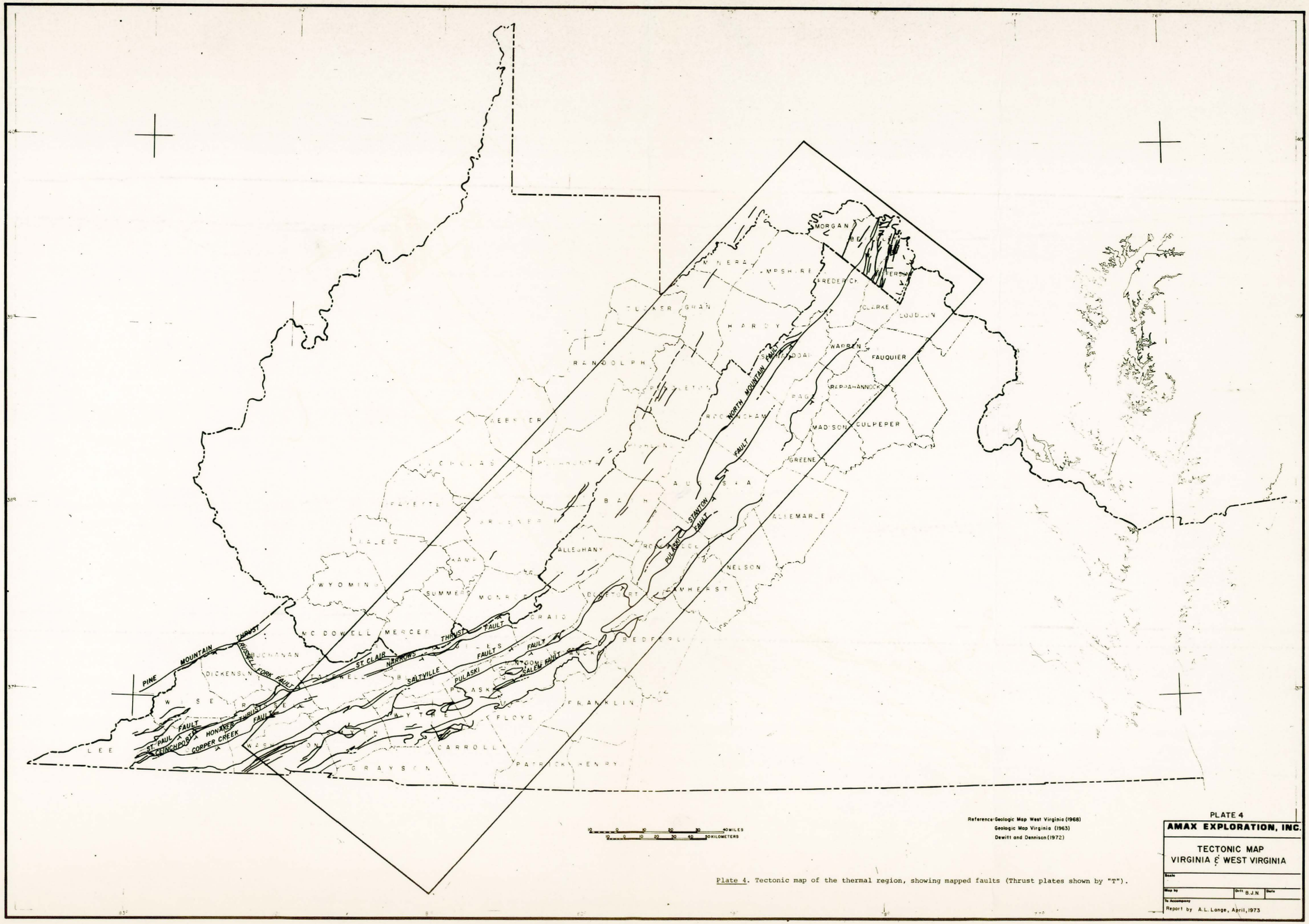


Plate 2B

Plate 2A. Generalized geologic profile along M-M' (See Plate 3). From BUTTS (1933).

Plate 2B. Topographic profile running NW-SE approximately through Hot Springs, Virginia.



Reference: Geologic Map West Virginia (1968)
Geologic Map Virginia (1963)
Dewitt and Dennison (1972)

Plate 4. Tectonic map of the thermal region, showing mapped faults (Thrust plates shown by "T").

PLATE 4

AMAX EXPLORATION, INC.

TECTONIC MAP
VIRGINIA & WEST VIRGINIA

Scale

Drawn by B.J.N. Date

To Accompany Report by A.L. Lange, April, 1973

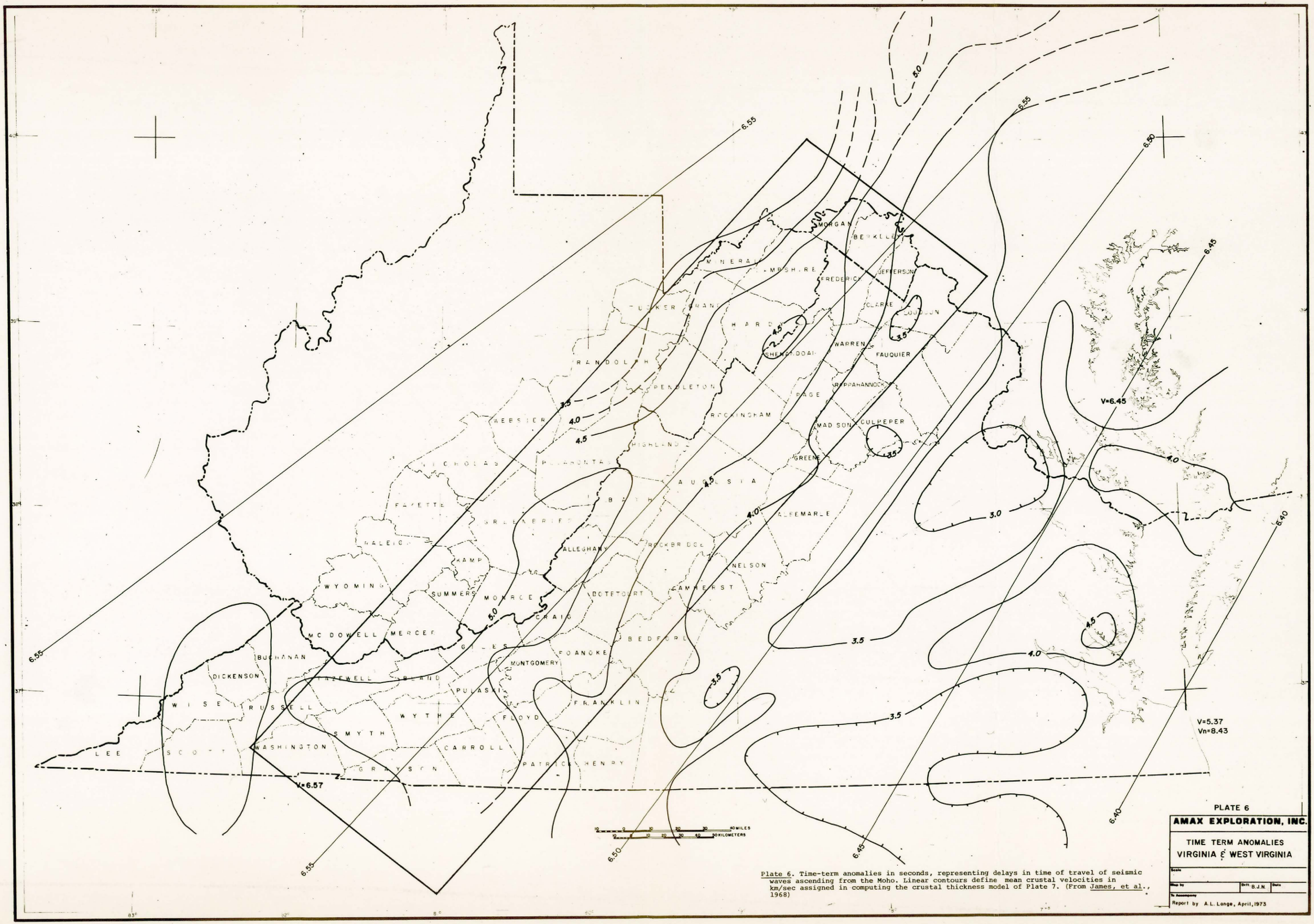


Plate 6. Time-term anomalies in seconds, representing delays in time of travel of seismic waves ascending from the Moho. Linear contours define mean crustal velocities in km/sec assigned in computing the crustal thickness model of Plate 7. (From James, et al., 1968)

PLATE 6

AMAX EXPLORATION, INC.

TIME TERM ANOMALIES
VIRGINIA & WEST VIRGINIA

Scale

Map by	Drft. B.J.N.	Date

To Accompany Report by A.L. Longe, April, 1973

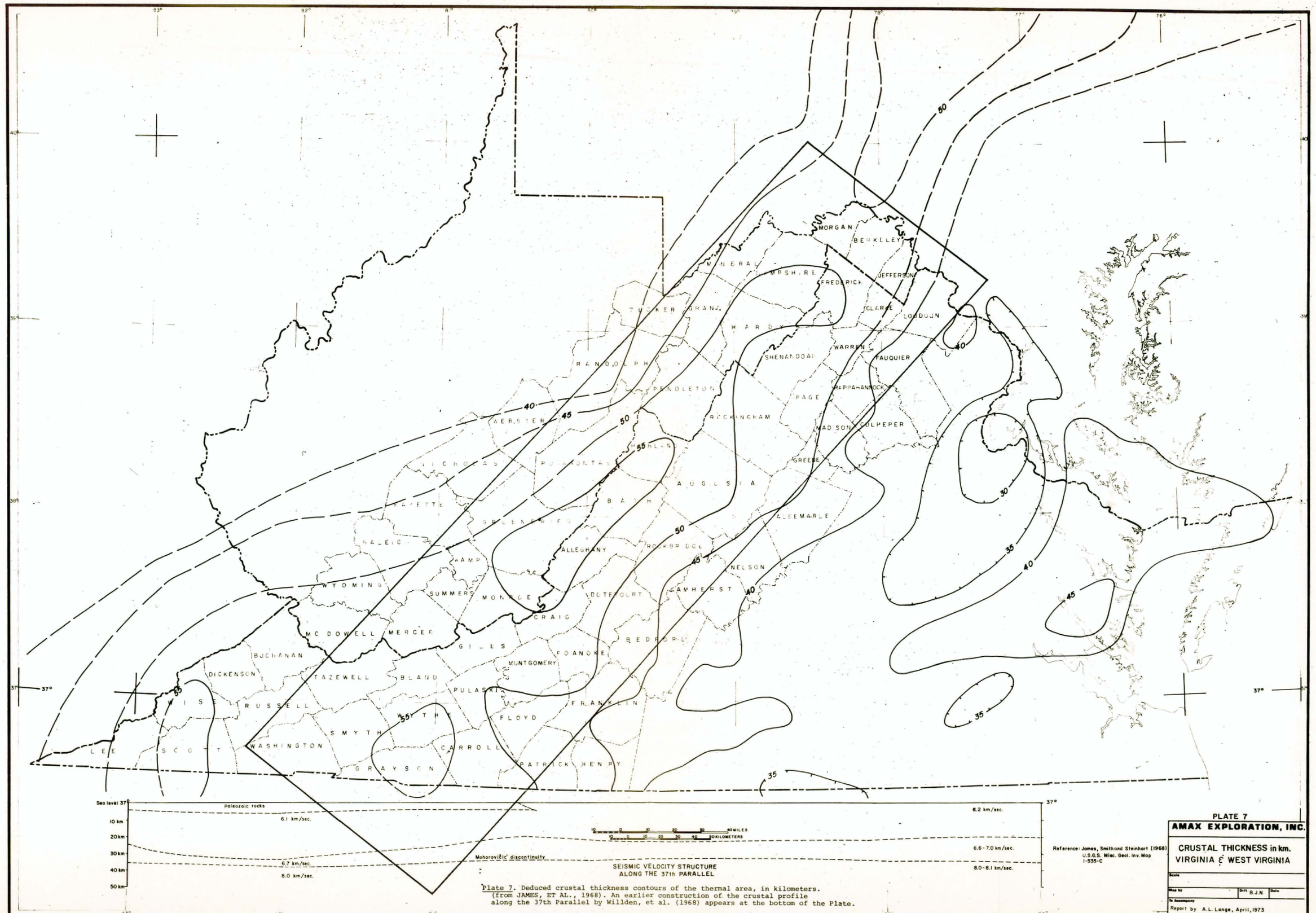


Plate 7. Deduced crustal thickness contours of the thermal area, in kilometers. (from JAMES, ET AL., 1968). An earlier construction of the crustal profile along the 37th Parallel by Willden, et al. (1968) appears at the bottom of the Plate.

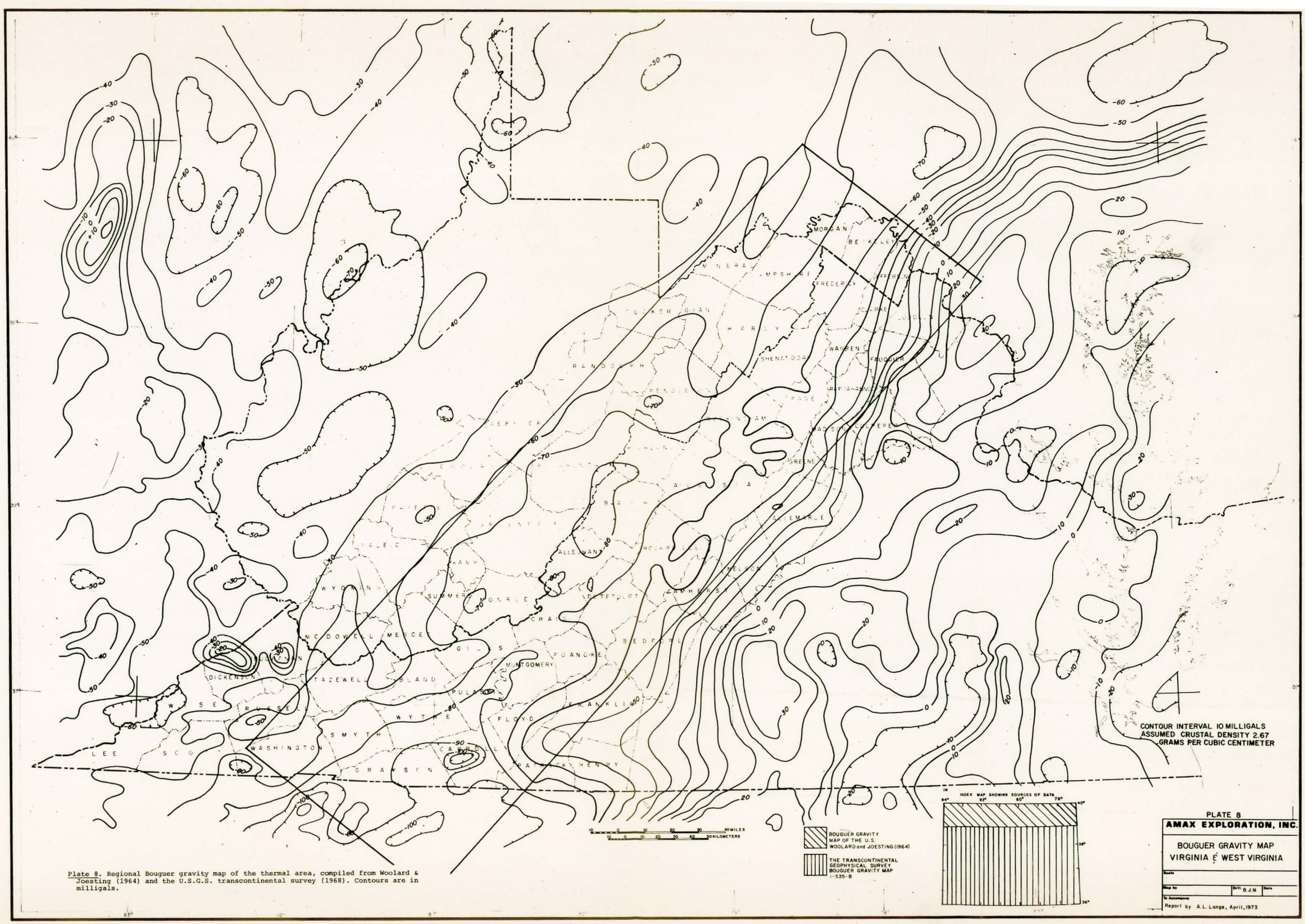


Plate 8. Regional Bouguer gravity map of the thermal area, compiled from Woolard & Joesting (1964) and the U.S.G.S. transcontinental survey (1968). Contours are in milligals.

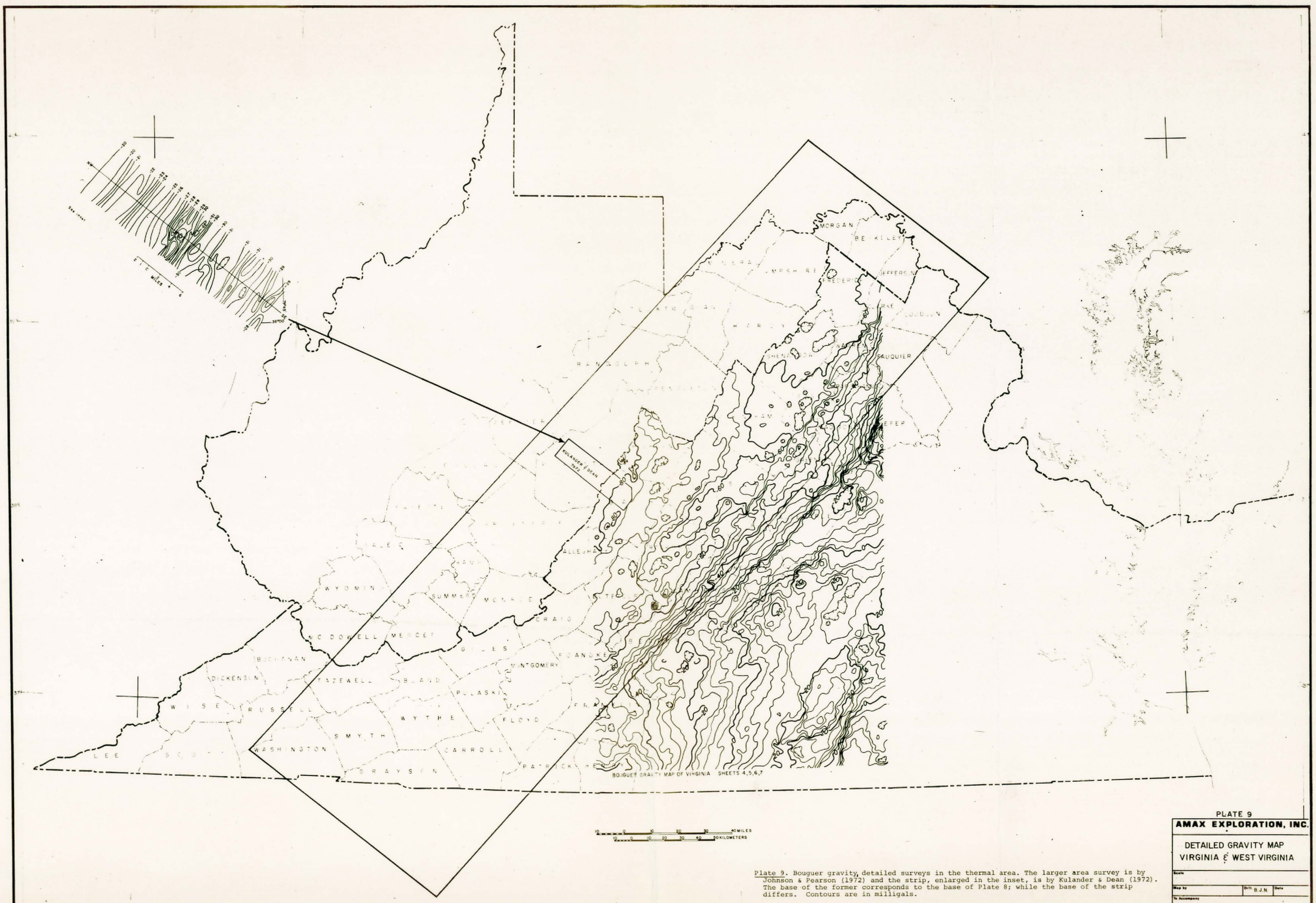


Plate 9. Bouguer gravity, detailed surveys in the thermal area. The larger area survey is by Johnson & Pearson (1972) and the strip, enlarged in the inset, is by Kulander & Dean (1972). The base of the former corresponds to the base of Plate 8; while the base of the strip differs. Contours are in milligals.

PLATE 9

AMAX EXPLORATION, INC.

DETAILED GRAVITY MAP
VIRGINIA & WEST VIRGINIA

Scale

Map by | Drft B.J.N. | Date

To Accompany Report by A.L. Longe, April, 1973

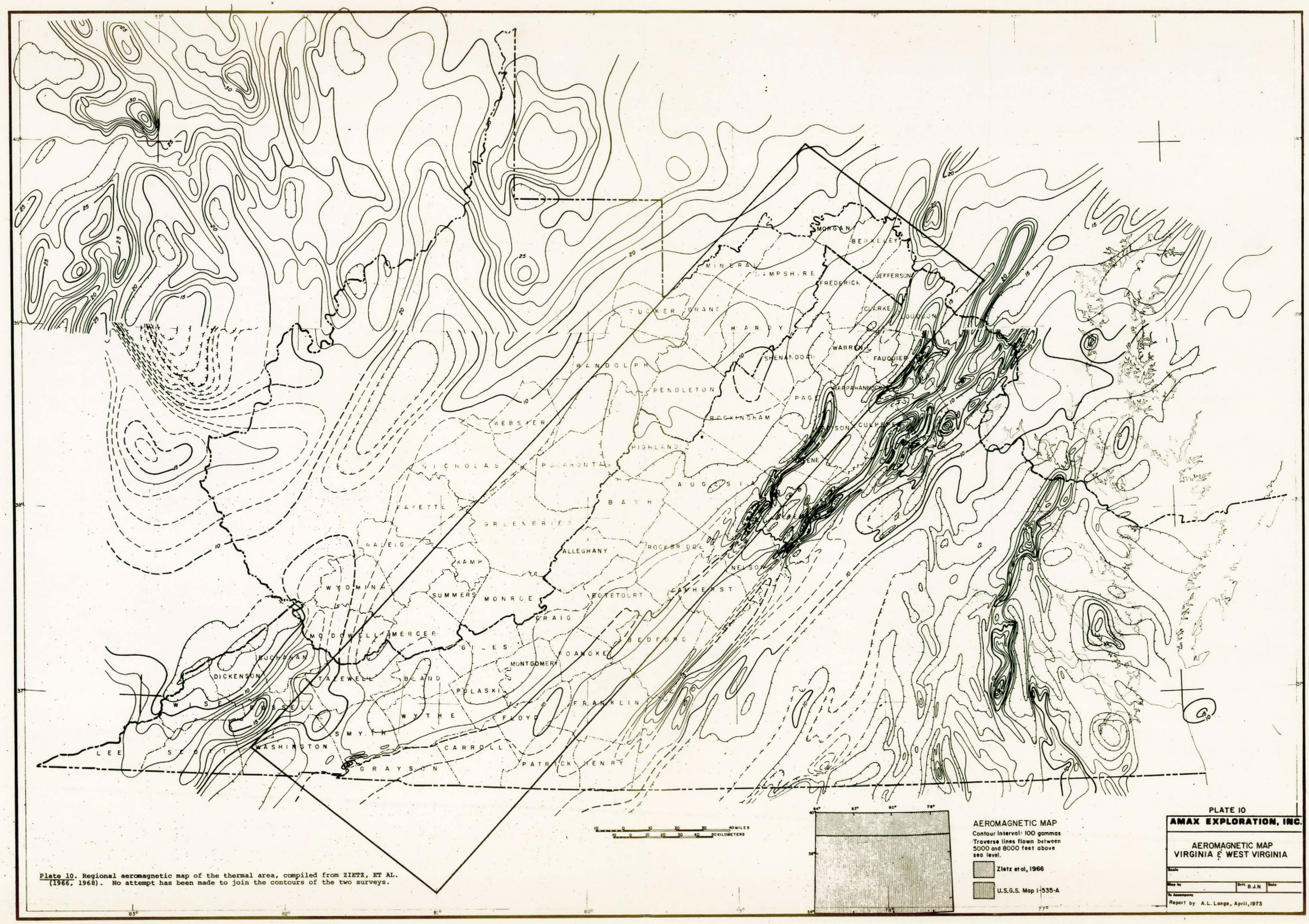


Plate 10. Regional aeromagnetic map of the thermal area, compiled from ZIETZ, ET AL. (1966, 1968). No attempt has been made to join the contours of the two surveys.

MORGAN
BERKELEY
JEFFERSON
FREDERICK
CLARKE
LOUDOUN
MINERAL
HAMPSHIRE
TUCKER
GRANT
HARDY
WARREN
FAUQUIER
SHENANDOAH
RANDOLPH
PENDLETON
RAPPAHANNOCK
PAGE
ROCKINGHAM
MADISON
CULPEPER
WEBSTER
HIGHLAND
GREENE
NICHOLAS
POCAHONTAS
AUGUSTA
FAYETTE
BATH
ALBEMARLE
GREENBRIER
RALEIGH
ALLEGHANY
ROCKBRIDGE
NELSON
KANAWHA
WYOMING
SUMMERS
MONROE
BOTETOURT
AMHERST
CRAIG
MERCER
MCDOWELL
GILES
BEDFORD
BUCHANAN
MONTGOMERY
ROANOKE
DICKENSON
TAZEWELL
BLAND
PULASKI
WISE
RUSSELL
WYTHE
FLOYD
FRANKLIN
SMYTH
WASHINGTON
CARROLL
LEE
SCOTT
GRAYSON
PATRICK HENRY

SEISMICITY 1754-1970

- Felt Reports
- II-III
- IV-V
- VI-VII
- VIII-IX
- X Two or more earthquakes

10 0 10 20 30 40 MILES
10 0 10 20 30 40 50 KILOMETERS

Plate 11. Seismicity of the thermal region, as compiled by Bollinger from instrumental and felt reports. Intensities, according to the Modified Mercalli Scale, not Richter magnitudes, are plotted.

PLATE II

AMAX EXPLORATION, INC.

SEISMICITY
VIRGINIA & WEST VIRGINIA

Drawn by B.J.N. Date

To Accompany

Report by A.L. Longe, April, 1973

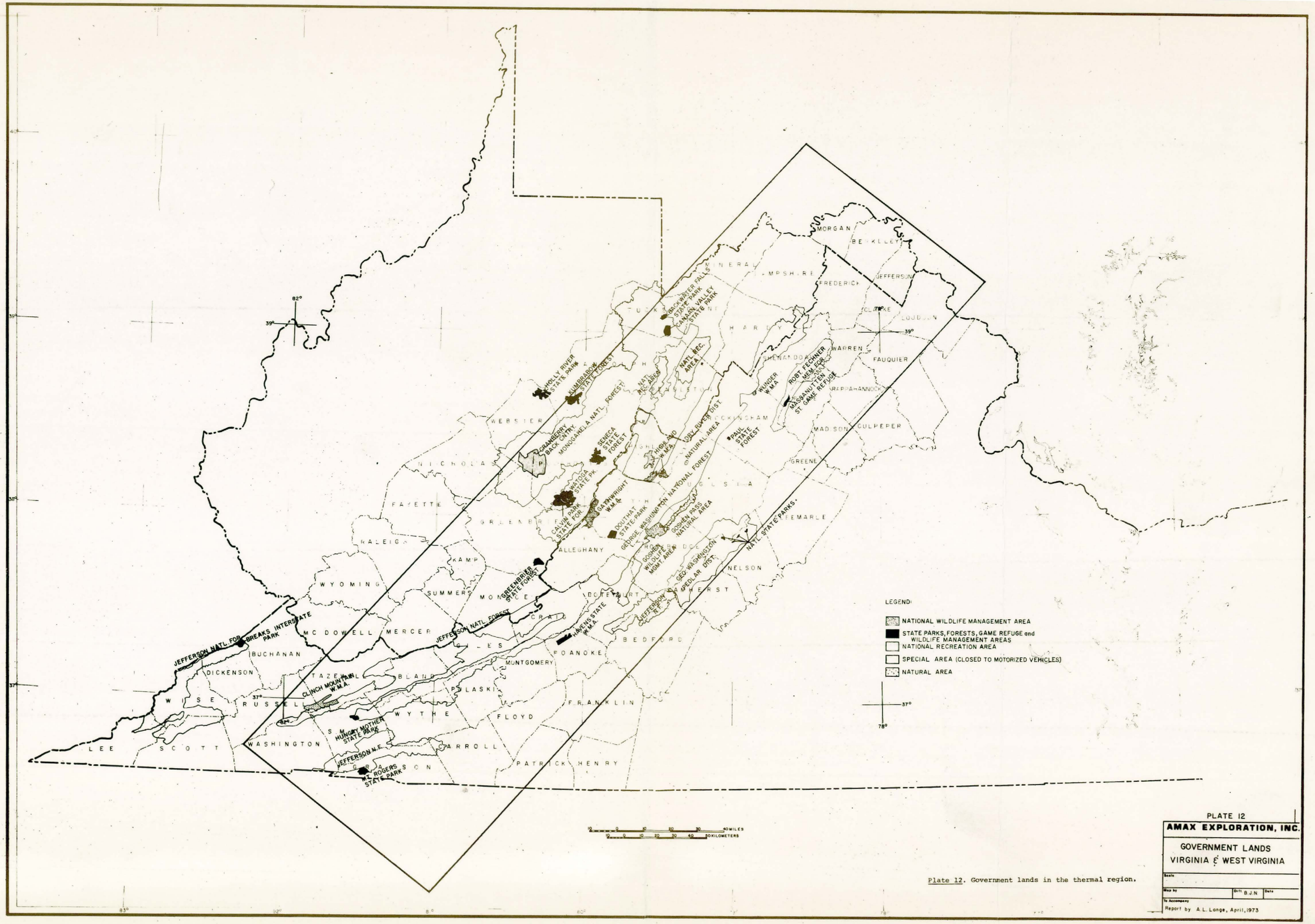


Plate 12. Government lands in the thermal region.

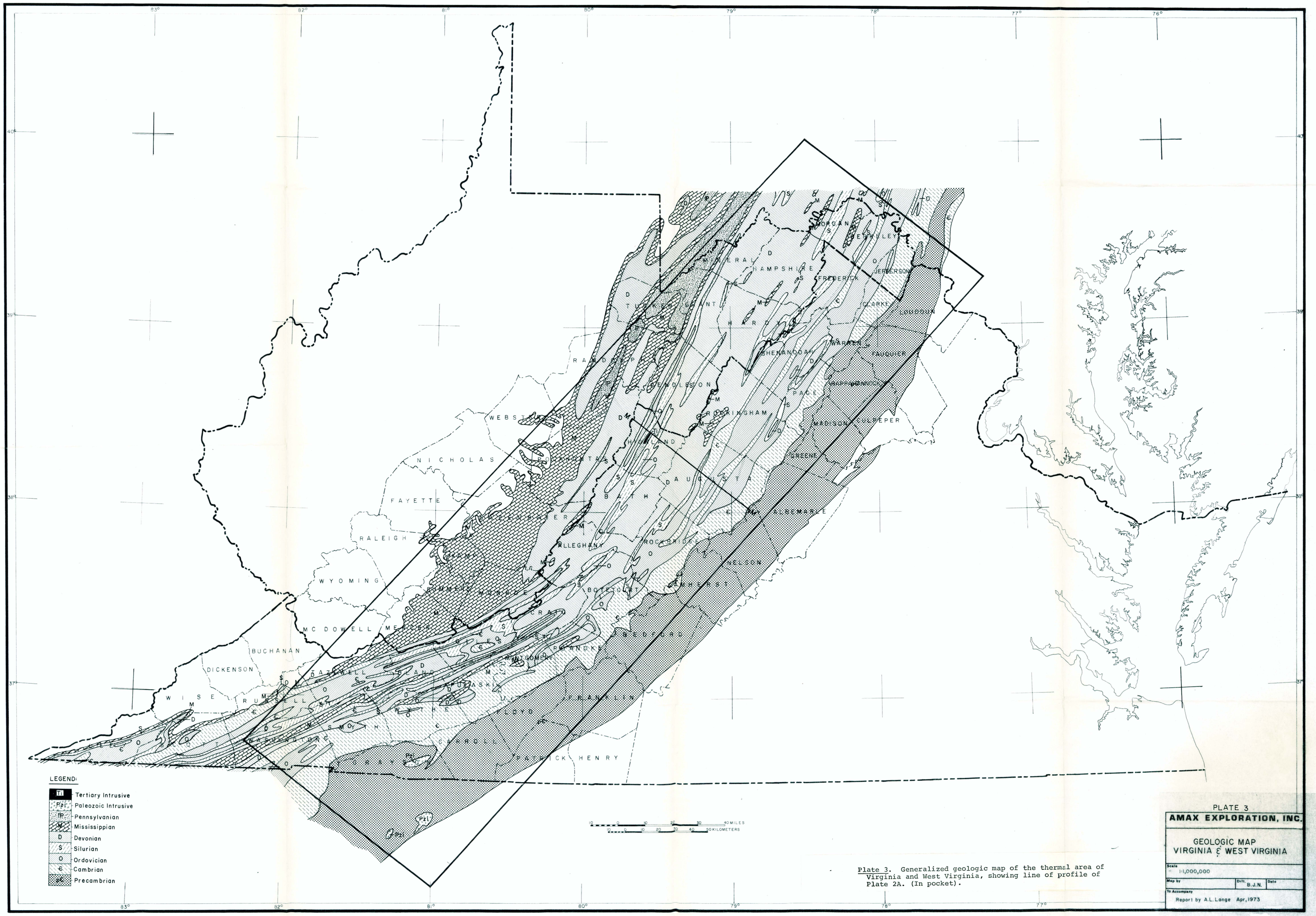


Plate 3. Generalized geologic map of the thermal area of Virginia and West Virginia, showing line of profile of Plate 2A. (In pocket).

PLATE 3

AMAX EXPLORATION, INC.

GEOLOGIC MAP
VIRGINIA & WEST VIRGINIA

Scale 1:1,000,000

Map by | Drft. B.J.N. | Date

To Accompany Report by A.L. Lange Apr, 1973

THERMAL SPRINGS*

LEGEND:

Temperature

	°F	°C
●	60-69	15.6 - 21.1
●	70-79	21.1 - 26.7
●	80-89	26.7 - 32.2
●	90-99	32.2 - 37.8
●	100-109	37.8 - 43.3

Discharge**

Magnitude	Gal./Min.	Ft.³/Sec.	Liters/Sec.
◯ I	>44,000	>100	>6308
◯ II	4,400-44,000	10-100	631-6308
◯ III	440-4,400	1-10	63.1-631
◯ IV	100-440	.22-1	6.31-63.1
◯ V	10-100	.022-.22	.631-6.31
◯ VI	1-10	.0022-.022	.063-.631
○ VII	1.25-1	.000275-.0022	.008-.063
○ VIII	<.125	<.000275	<.008
◌	No Data		

* Max. Published Temperature ≥60°F (15.6°C)
**Mean of Published Values; Discharge ranges include lower values but exclude upper.

HEAT FLOW VALUES

Gradient (°C/km)
Heat Flow (micro calories/cm² sec.)

△ Lee & Uyeda (1965)
□ J. Costain (pers. comm.)
▲ Reiter & Costain (1973)

⊕ DEEP WELL

△ 29/1.22
△ 37/1.26?
△ 34/1.20
▲ 7.2-25.7/1.7
▲ <13./1.03
□ ?/.78
△ 18/1.4

BERKELEY SPGS.
WARM SPGS.
HOT SPG.
HEALING SPGS.
WHITE SULPHUR SPGS.
WARM RIVER CAVE
SWEET SPGS.
NEW RIVER
BOLAR SPGS.
SPONAUGLE WELL
W-1432
USA-357

MORGAN, BERKELEY, MINERAL, HAMPSHIRE, FREDERICK, JEFFERSON, CLARKE, LOUDOUN, TUCKER, GRANT, HARDY, WARREN, SHENANDOAH, FAUQUIER, RANDOLPH, PAGE, RAPPAHANNOCK, WEBSTER, HIGHLAND, MADISON, CULPEPER, GREENE, NICHOLAS, AUGUSTA, FAYETTE, GREENBRIER, ALLEGHANY, ROCKBRIDGE, NELSON, RALEIGH, KANAWHA, WYOMING, SUMMERS, MONROE, BOTETOURT, AMHERST, GILES, ROANOKE, BEDFORD, DOWELL, MERCER, BUCHANAN, MONTGOMERY, DICKENSON, TAZEWELL, BLAND, PULASKI, FRANKLIN, WISE, RUSSELL, WYTHE, FLOYD, SMYTH, CARROLL, LEE, SCOTT, WASHINGTON, GRAYSON, PATRICK HENRY

10 0 10 20 30 40 MILES
10 0 10 20 30 40 50 KILOMETERS

Plate 5. Thermal springs, heat flow values and deep well locations. Documentation of springs appears in Table 3.

PLATE 5

AMAX EXPLORATION, INC.

THERMAL SPRINGS & HEAT FLOW
VIRGINIA & WEST VIRGINIA

Scale 1:1,000,000

Map by | Drft B.J.N. | Date

To Accompany Report by A.L. Lange, April, 1973

VIRGINIA COMMISSION OF GAME AND INLAND FISHERIES

US FOREST SERVICE, DEPARTMENT OF AGRICULTURE

GEORGE WASHINGTON NATIONAL FOREST

WARM SPRINGS DISTRICT

LEGEND

State Boundary
County Boundary
National Forest Boundary
Interstate Route
Federal Route
State Route
Dirt Road
Forest Service Road
Trail & Foot Path
Railroad
Electric, Power Line; Pipeline
Forest Service Land
National, State Park
Wildlife Management Area
Airfield
Forest Supervisor's Headquarters
District Ranger Station
Campsite
Picnic, Recreation Area
Launching Ramp
Fish Hatchery
Parking Area
Point of Interest
Lookout Tower
Stocked Trout Stream — BUCK RUN

SCALE: 1 INCH = 2 MILES

1 ½ 0 1 2 3 4

CONTOUR INTERVAL 200 FEET

Polyconic Projection - North American Datum

LAND STATUS JUNE 1972

Plate 13. Warm Springs District of George Washington National Forest, showing private lands within the National Forest boundaries. (In pocket)

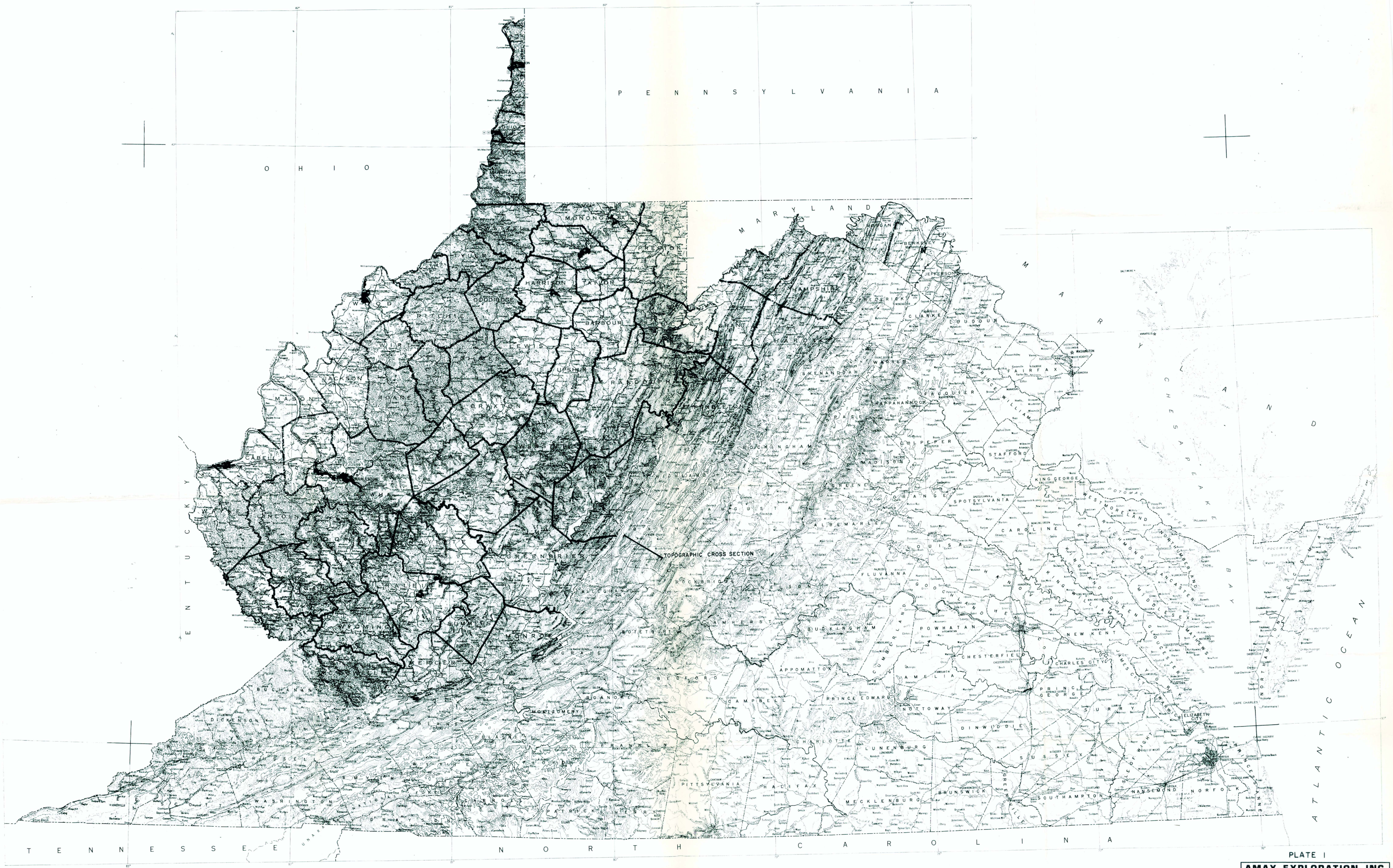


Plate 1. Topographic map of Virginia and West Virginia showing line of profile of Plate 2B. (In pocket).

PLATE I

AMAX EXPLORATION, INC.

TOPOGRAPHY
VIRGINIA & WEST VIRGINIA

Scale			
1:1,000,000			
Map by		Drft. B.J.N	Date
To Accompany			
Report by A.L. Lange Apr, 1973			

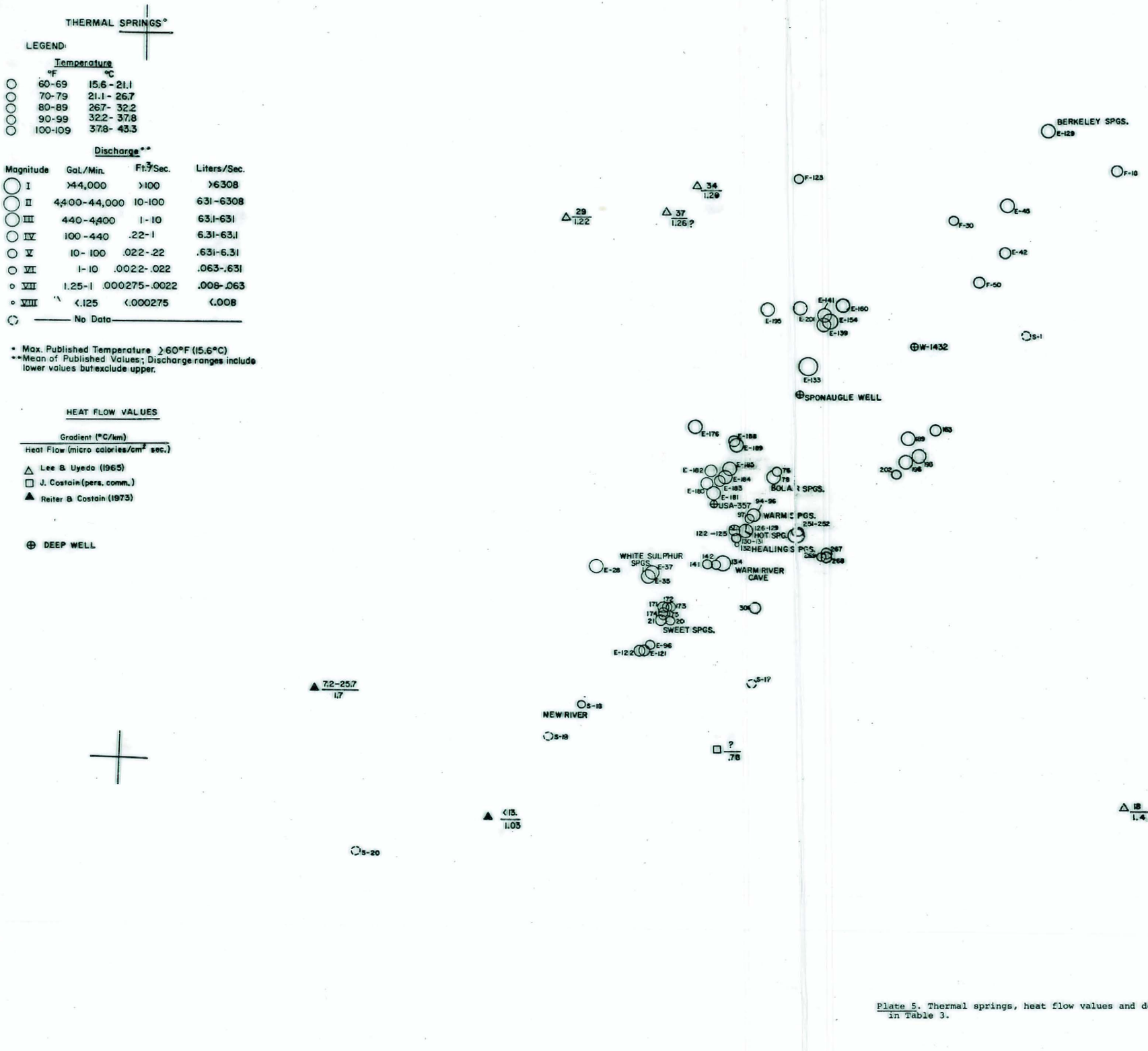


Plate 5. Thermal springs, heat flow values and deep well locations. Documentation of springs appear in Table 3.

VIRGINIA COMMISSION OF GAME AND INLAND FISHERIES

US FOREST SERVICE, DEPARTMENT OF AGRICULTURE

GEORGE WASHINGTON NATIONAL FOREST

WARM SPRINGS DISTRICT

LEGEND

State Boundary
County Boundary
National Forest Boundary
Interstate Route
Federal Route
State Route
Dirt Road
Forest Service Road
Trail & Foot Path
Railroad
Electric, Power Line; Pipeline
Forest Service Land
National, State Park
Wildlife Management Area
Airfield
Forest Supervisor's Headquarters
District Ranger Station
Campsite
Picnic, Recreation Area
Launching Ramp
Fish Hatchery
Parking Area
Point of Interest
Lookout Tower
Stocked Trout Stream — BUCK RUN

SCALE: 1 INCH = 2 MILES

1 ½ 0 1 2 3 4

CONTOUR INTERVAL 200 FEET

Polyconic Projection - North American Datum

LAND STATUS JUNE 1972

Plate 13. Warm Springs District of George Washington National Forest, showing private lands within the National Forest boundaries. (In pocket)