GEOLOGY OF THE MID-ATLANTIC MARGIN OF THE NORTH AMERICAN CONTINENT
ROCKS AND SEDIMENTS OF A WIDE RANGE OF AGES
MID-ATLANTIC MARGIN TECTONICS

CENOZOIC

<table>
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<th>65 M</th>
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MESOZOIC

| ~187 M |
| 65 Ma  |

PALEOZOIC

| ~190 M |
| 252 Ma |

PRECAMBRIAN

| ~3.7 B |
| 541 Ma |

- Chesapeake Invader (~35 Ma)
- Chicxulub Impact (65 Ma)
- Newark Rifting (220-175 Ma)
- Alleghanian Orogeny (260-325 Ma)
- Acadian Orogeny (325-375 Ma)
- Taconic Orogeny (440-540 Ma)
- Grenville Orogeny (960 Ma-1.3 Ga)

- Continental drift and a passive margin
- Episodic continental convergence, rifting, and drifting, mostly active margin

- Oldest oceanic crust

- Large-bolide impact

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Grenville Orogeny
960 Ma-1.3 Ga

Taconic Orogeny
440-540

Acadian Orogeny
325-375

Alleghanian Orogeny
260-325

Newark Rifting
220-190?

Grenville orogeny (1 b.y. ago)
Post-Granville rifting (~500 m.y. ago)
Cambro-Ordovician passive margin
Avalonia
Avalonia
Acadian orogeny (Devonian)
Avalonia
Africa
Alleghanian orogeny (Carboniferous-Permian)
Triassic-Jurassic rifting

Present day
Plateau Valley & Ridge Highlands Newark basin Coastal Plain Atlantic
**GRENVILLE OROGENY**

1.3 Ba - 960 Ma

- *The Grenville Orogeny was a long-lived, very old mountain-building event associated with the assembly of the supercontinent Rodinia.*

- Its record is a prominent orogenic belt which spans a significant portion of the North American continent, from Labrador to Mexico, as well as to Scotland.

- Orogenic crust of mid-late Proterozoic age is found worldwide, but generally, only events which occurred on the southern and eastern margins of Laurentia are recognized under the “Grenville” name (Kibaran orogeny in Africa, and the Dalslandian orogeny in western Europe).
TACONIC AND ACADIAN OROGENIES 540-325 Ma

- Proto North America (PNA) about 430 million years ago, with Greenland nested against northern Canada.
- PNA is straddling the equator, the present "east coast" is closer to being a "south coast", and much of the US and Canada was covered by shallow seas.

- Baltica, the core of western Europe, moving westward, made impact against Greenland, and raised mountains on both continents.
- The Taconic island chain (TAC) began to collide with Proto North America about 40 million years earlier (470 to 450 million years ago).
- The Iapetus Ocean, which had been the shoreline for Proto North America, is closing as Western and Eastern Avalonia (WAV and EAV), following behind the Taconic arc, are heading for collision with the recently-extended coast of Proto North America.
- A wide swath of Iapetus Ocean seafloor material will be pushed onto Proto North America as the Avalonian islands push against and onto Proto North America.

Dr. Ron Blakely, Northern Arizona University

http://www.jamestown-ri.info/acadian.htm
• *The Alleghanian orogeny is the suturing of two continents into the supercontinent Pangaea.*
ALLEGHANIAN OROGENY

- Orogenesis occurred approximately 325 million to 260 million years ago over at least five deformation events in the Carboniferous to Permian period.
Approximately 220 million years ago, during the late Triassic Period, the supercontinent Pangaea began to break apart. The focus of the rifting began somewhere between where present-day eastern North America and north-western Africa were joined.

The rifted margins subsided, forming basins in which continental and marine sediments accumulated with evaporites forming in restricted basins.

Sills, dikes and lava flows were injected into predominantly non-marine sediments during the early (Triassic) history.
PASSIVE (?) DRIFT

175 (?) Ma - 0

- The rate of subsidence slowed with time as the margin cooled, but the accumulating sediment contributed to the sink rate.

- Following the rifting and initial accretion of oceanic crust, the Atlantic grew to over 1,000 kilometers wide during the Jurassic, but this early ocean was shallow because it was over the spreading center.

- During the late Cretaceous and Cenozoic, the controls on shelf sedimentation were regional warping and faulting and eustatic sea level changes.

- Subsidence with sediment influx and accumulation of sediments continued on the shelf and a continental rise was developed by turbidity current deposits from the shelf and slope.

- The North American continent is growing along the Atlantic slope and the shelf break advances seaward as sediments accumulate over older strata. The sequence in the growth of the Atlantic margin is a model for divergent margin development.

- No mention of impact tectonic effects in the current geological tectonic framework.
ARCHITECTURE OF THE EASTERN MARGIN OF THE NORTH AMERICAN PLATE

- The eastern seaboard of the North American continent is scalloped with a series of concave and convex regions stemming from overlapping, orogenic (and impact) events.

- Angular bends (promontories and embayments) in rifted and passive continental margins are interpreted to be the precursors of curves (recesses and salients, respectively) in orogenic belts.

1983, Continental margins, orogenic belts, and intracratonic structures, William A. Thomas, Department of Geology, University of Alabama, Tuscaloosa
Plate convergence at an irregularly shaped continental margin results in along-strike diachronieity of closing (and thus of orogeny) and in a variable trajectory of stress into continental crust.
PALINSPASTIC INTERPRETATION OF THE PENNSYLVANIA SALIENT

- Blind-thrust, foreland fold-and-thrust belt of Alleghanian age.
Figure 8. - Development of the stiff layer. The configuration of the outcropping stiff layer slices and the cover layer combine to help position other thrust slices. Refer to text for further explanation.
PENETRATIVE COVER STRAINS
NEW YORK RECESS

Mid-Atlantic margin of the North American Plate, The York Recess

Default view for

L10_Mid-Atlantic_Geology.kmz
NEW YORK RECESS

Mid-Atlantic margin of the North American Plate, The York Recess

• Two regional bedrock geological studies between 1984 and 1997.
NEW YORK RECESS

Mid-Atlantic margin of the North American Plate, The York Recess
PRECAMBRIAN IGNEOUS AND GRANULITE FACIES BASEMENT MASSIFS
MIXED EARLY PALEOZOIC AND PRECAMBRIAN SCHIST AND METAMORPHIC ROCKS
PALEOZOIC ROCKS

• LOWER, MIDDLE, AND UPPER
MESOZOIC ROCKS

- Late Triassic and Early Jurassic Newark Basin
- Gettysburg Basin
- Hartford Basin
- Cretaceous marine sands and clays
ALL ROCKS SHOWING MAJOR FAULTS AND GLACIAL MORAINES
NEW JERSEY HIGHLANDS

- Scenic and rugged terrain
- Mountainous uplands
- Northeast-trending ridges
- Rocks resistant to erosion
- Broad, flat valleys underlain by less resistant Proterozoic rocks and/or younger shale and limestone/dolomite
HIGHLANDS GRANITE 50% of outcrop area

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HIGHLANDS GNEISS AND MARBLE

50% of outcrop area

Igneous gneiss

Marble and Sedimentary gneiss

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HIGHLANDS FOLDS

[Images of rock formations with labels: 1 in., 1 ft, folding, anticline, syncline, compression.]
HIGHLANDS STRUCTURE 3D Google Earth View of NJ Bedrock Section A-A’


- NJ_Bedrock_cross_section_A.kmz (253 KB)
VALLEY & RIDGE  

About 1/15th of NJ on its NW edge

- Steep sided ridges and broad valleys composed of folded and faulted Paleozoic sedimentary and igneous rock (Cambrian-Middle Devonian 540-374 Ma)
VALLEY & RIDGE ROCKS

Limestone - dissolves with acid, weathers easily

Sandstone - more resistant to weathering where cemented

Quartzite - very resistant, forms Kittatinny Mountain

Slate or shale – resistant to weathering, thin soils,

Dolomite - a carbonate, dissolves with acid, weathers easily

Sandstone - more resistant to weathering where cemented

Quartzite - very resistant, forms ridges

Granite and gneiss of the Highlands
VALLEY & RIDGE STRUCTURES

- Folds
- Cleavage
- Fractures
- Faults
NJ RIDGE AND VALLEY THRUST SYSTEM

- Multiply-tectonized foreland riding northwestward on a hypothetical decollement

- Cleavage

- Fractures

- Faults
Figure 1. Map showing study area, physiographic provinces, deep seismic reflection lines, wells, and trace of schematic cross section. Dotted-line arrows illustrate projection of seismic line data into corresponding cross-section interval.
SEISMIC-REFLECTION SURVEYS

Field Setup

List of Equipment
- Recorder: Data Physics Corp. 4 channel Quattro analyzer *1
- Receivers: Sercel Inc. 1 Hz Geophone (L4) * 3
- Sources: 10 lb Sledge Hammer * 1 for close receiver spacing (< 16 ft)
  + Thumper Shaker for longer receiver spacing (30 ft to 300 ft)

Source Thumper @ 60 ft
Receiver 1 @ 30 ft
Receiver 2 @ 0 ft
Receiver 3 @ -60 ft

Seismic reflection method. Vibroseis sound source with geophone spread.

VIBROSEIS TRUCKS

www.horizonglobal.co/gallery.html
Figure 6. Borehole data for the Texaco well C-1 showing a stratigraphic correlation to the northwest end of Exxon profile SD-11. The borehole compensated sonic log and conventional velocity analysis are by Texaco. The synthetic seismogram was generated by Exxon. See text for further discussion.
UNINTERPRETED SEISMIC-REFLECTION PROFILE
Figure 9. Exxon seismic-reflection profile SD-13. TWT—two-way traveltime. Geologic interpretations are shown for both the migrated, full display (top) and the conventional line drawing of the unmigrated profile (bottom). Abbreviations and symbols as in Figures 7 and 8.
PALINSPASTIC CROSS-SECTION INTERPRETATIONS

CARBONATE PLATFORM WITH FORELAND FOLDS

POST-TACONIC

PASSIVE MARGIN CARBONATE PLATFORM

PRE-TACONIC

Tripartite stratigraphy of the Shawangunk Fm. in the NJ Valley & Ridge Province (Epstein, 1993).

Overlapping fans and distributary channels with polymict pebble and cobble strata reflecting local paleosurfaces.

Polymeric cobble and pebble conglomerate, quartzite and mélange.

Lower Paleozoic cover

Late Ordovician Beemerville Intrusive Complex

folding in Middle Proterozoic basement

Stylized post-Taconic fold-and-thrust belt across northern NJ

Restored position of the Green Pond Syncline

rising hinterland source area

eroded Lower Paleozoic cover

current erosion surface

faults

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Figure 16. Cross section A–A’ showing present-day and retrodeformed structures and the methods for deriving tectonic dimensions (see Table 2). The d2 position of the basement cover is shown superimposed on d3 (upper figure) to illustrate the structural-relief modeling assumption explained in the text. Rock-unit abbreviations are as in Figure 7.
NJ RIDGE AND VALLEY THRUST TOPOGRAPHIC RELIEF

10x vertical exaggeration

LITHOLOGY
- turquoise: dolomite
- green: granite
- yellow: quartzite
- brown: sandstone
- light green: gneiss
- blue: limestone
- orange: slate

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Flat lying outcrop of Allentown Dolomite showing widening of joints through solution

Sinkholes are most often the result of the collapse of soil and loose weathered rock into underlying cavities and solution joints.
KITATTINNY VALLEY STRUCTURES

SPACED, SLATY, AND CRENULATION CLEAVAGE

Figure 6. Folding of calcareous silt bed in Martinburg shale, 1/2 miles northwest of Bedloesia on U. S. 49.

Figure 7. Shearing and transport parallel to slaty cleavage, affecting calcareous siltstone bed. Same location as Figure 6. Solid black area is quartz-carbonate vein.
PIEDMONT PROVINCE

- Underlies most urban part of state ~ 1/5 NJ
- Low rolling plain divided by series of higher ridges
- Mostly underlain by slightly folded and faulted Mesozoic sedimentary and igneous rocks
NEWARK BASIN PART OF THE PIEDMONT PROVINCE
MESOZOIC HALF-GRABEN RIFT BASIN

• Tilted gently NW, faulted on the NW, and hinge on the SE

• Intruded by diabase and flooded by basalts ~ 200 Ma.

• Major intrabasinal faults
UPPER MESOZOIC (CRETACEOUS) to CENOZOIC PASSIVE MARGIN

- Subsidence with sediment influx and accumulation, turbidity currents depositing sediment onto and outward off the shelf, down the continental slope, and onto the continental rise.
- The North American continent is growing along the Atlantic slope and the shelf break advances seaward as sediments accumulate over older strata.
COASTAL PLAIN STRUCTURE

- Tilted gently SE
- No recognized faults at the surface
COMPOSITE STRUCTURAL PROFILE ACROSS THE NEW YORK RECESS

- Coastal plain sediments
- Newark basin rocks
- Marcellus Fm. through Catskill Fm.
- Wills Creek - Pocono Islands Fms. through Onondaga Fm. - Buttermilk Falls Limestone
- Tuscarora - Shawangunk Fms. through Bloomsburg Red Beds
- Martinsburg Fm.
- Cambrian-Ordovician carbonate rocks

Proterozoic Grenville basement (may include lower Paleozoic rocks where queried)

* Structurally complex domain reportedly composed of accreted metasedimentary, metavolcanic, and ophiolitic rocks related to the Taconic suture and other orogenic events. Mesozoic basins may also occur in these intervals.
QUATERNARY GLACIAL COVER

- Limited in extent to the northern 1/3 of New Jersey
- Generally very good aquifer where greater than 100’ thick in buried valleys.

This map shows some of the data included in DGS 96-1.
NEOTECTONICS AND FRACTURE DIP

New Jersey – New York USA historical seismicity (Sykes, 2006), vertical crustal motion (mm/yr) based on continuously-operated receiving stations in 2010 (CORS), and predicted neotectonic fracture strike and dip directions.