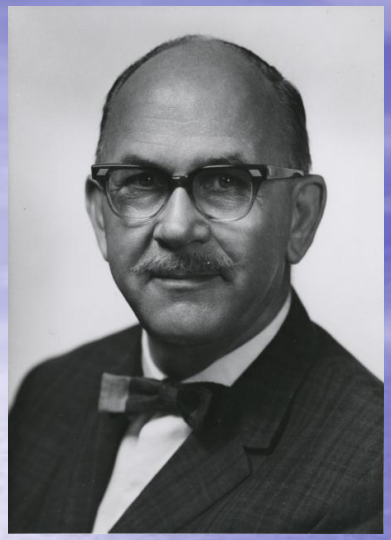


PROFESSOR ARTHUR B. CLEAVES – AN ENGINEERING GEOLOGY PIONEER

J. David Rogers, Ph.D., P.E., P.G.
Missouri University of Science & Technology

for Technical Session #18 on

A Special Tribute to Dr. Terry R. West

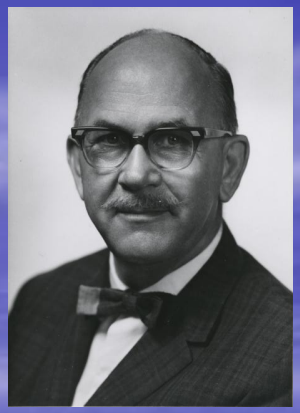
Annual Meeting
Association of Environmental & Engineering Geologists
New Orleans
Sept. 19, 2008

Online at: www.mst.edu/~rogersda

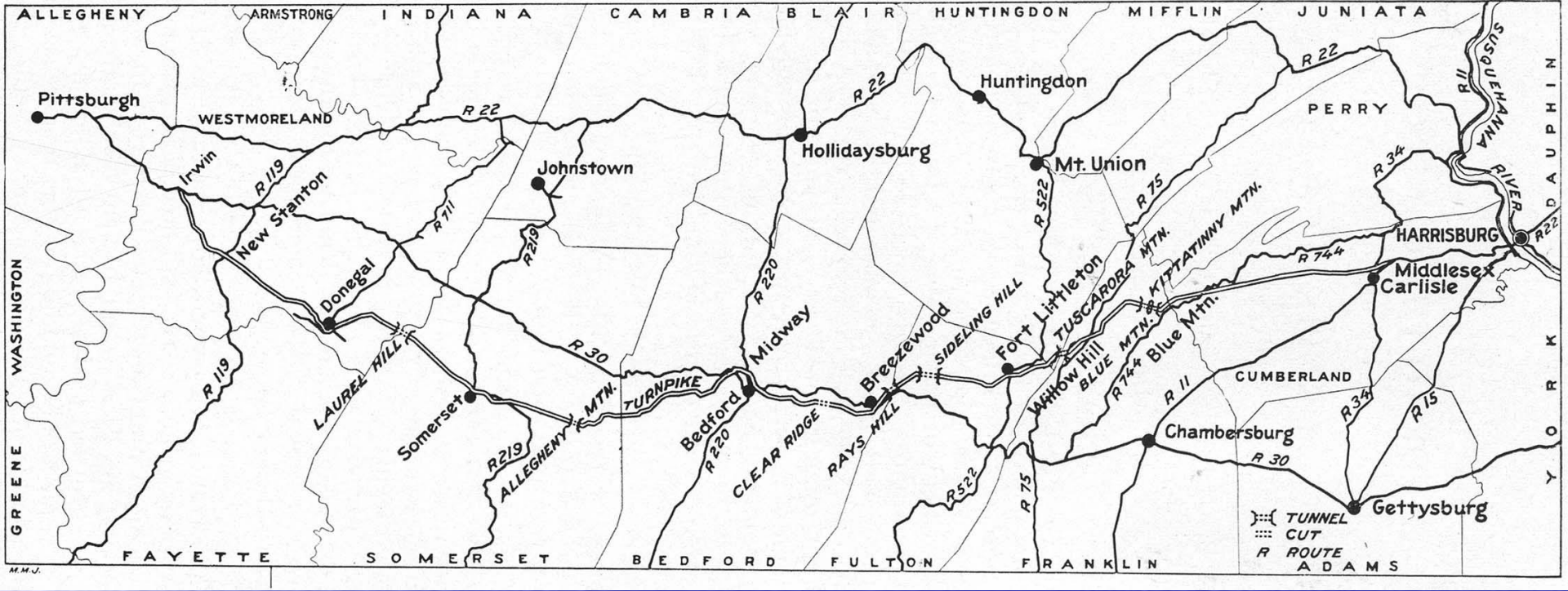
MISSOURI S&T University of Science & Technology

ENVIRONMENTAL ENGINEERING AEG GEOLOGISTS

Arthur B. Cleaves 1905-85



- Arthur Bailey Cleaves was born in North Scituate, MA in 1905. Between 1923-33 he earned five degrees in geology, from Brown, Toronto, and Harvard Universities.
- His early career included two years as an instructor at Lafayette Collage, two years with the Pennsylvania Geological Survey, and three years as Chief Geologist with the Pennsylvania Turnpike Commission, with whom he maintained a working relationship for over the next 22 years.



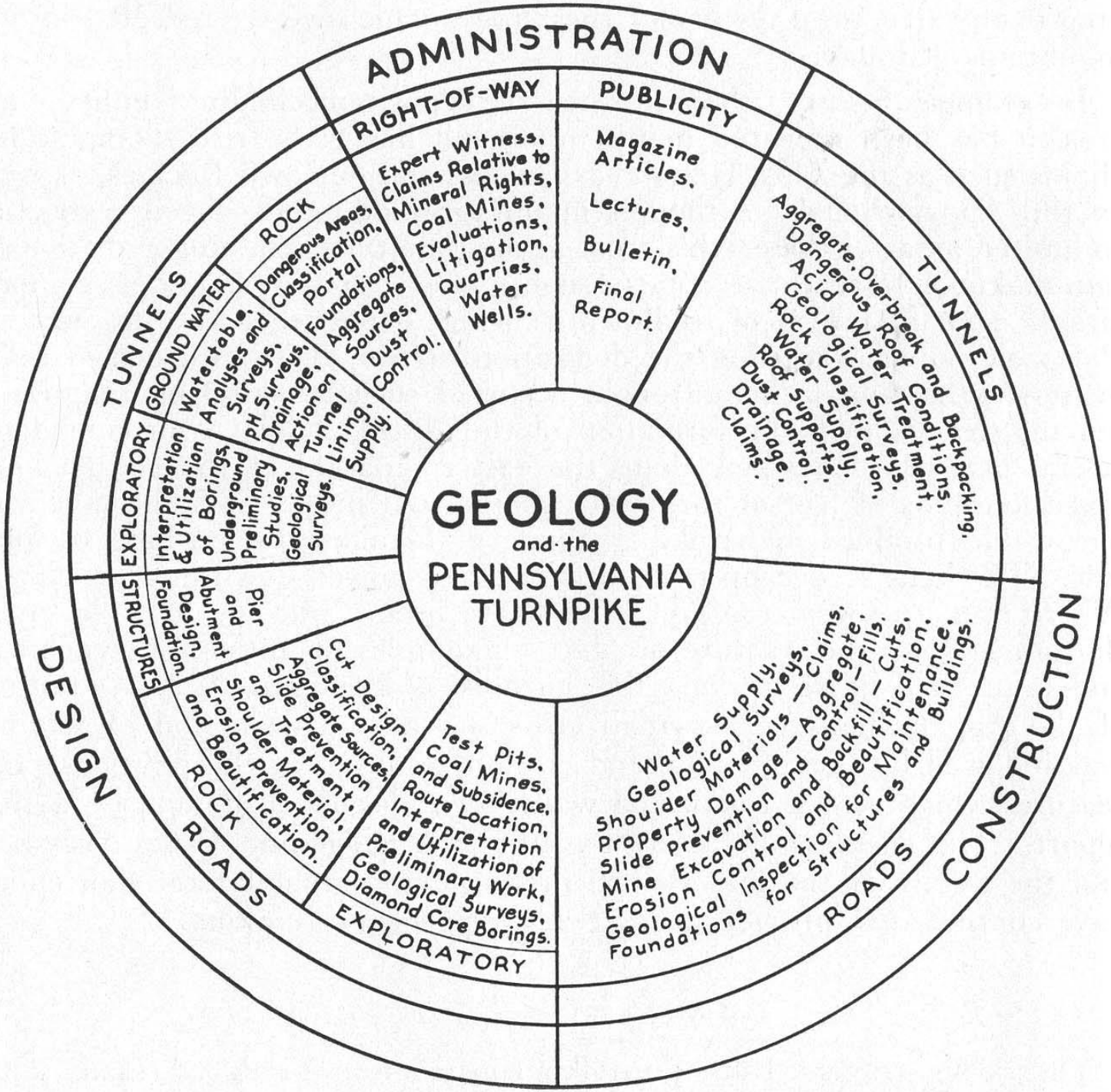
- In 1759 General John Forbes completed a major southern road from Shippensburg thru Bedford to Pittsburgh.
- In 1883 Andrew Carnegie teamed with William Vanderbuilt to build the South Penn Railroad more or less along the same alignment as the old Forbes Road
- By 1885 60% of the grade was completed, including 9 tunnels (4.5 miles), but the project fell into financial problems and was absorbed by the competing Pennsylvania Railroad.

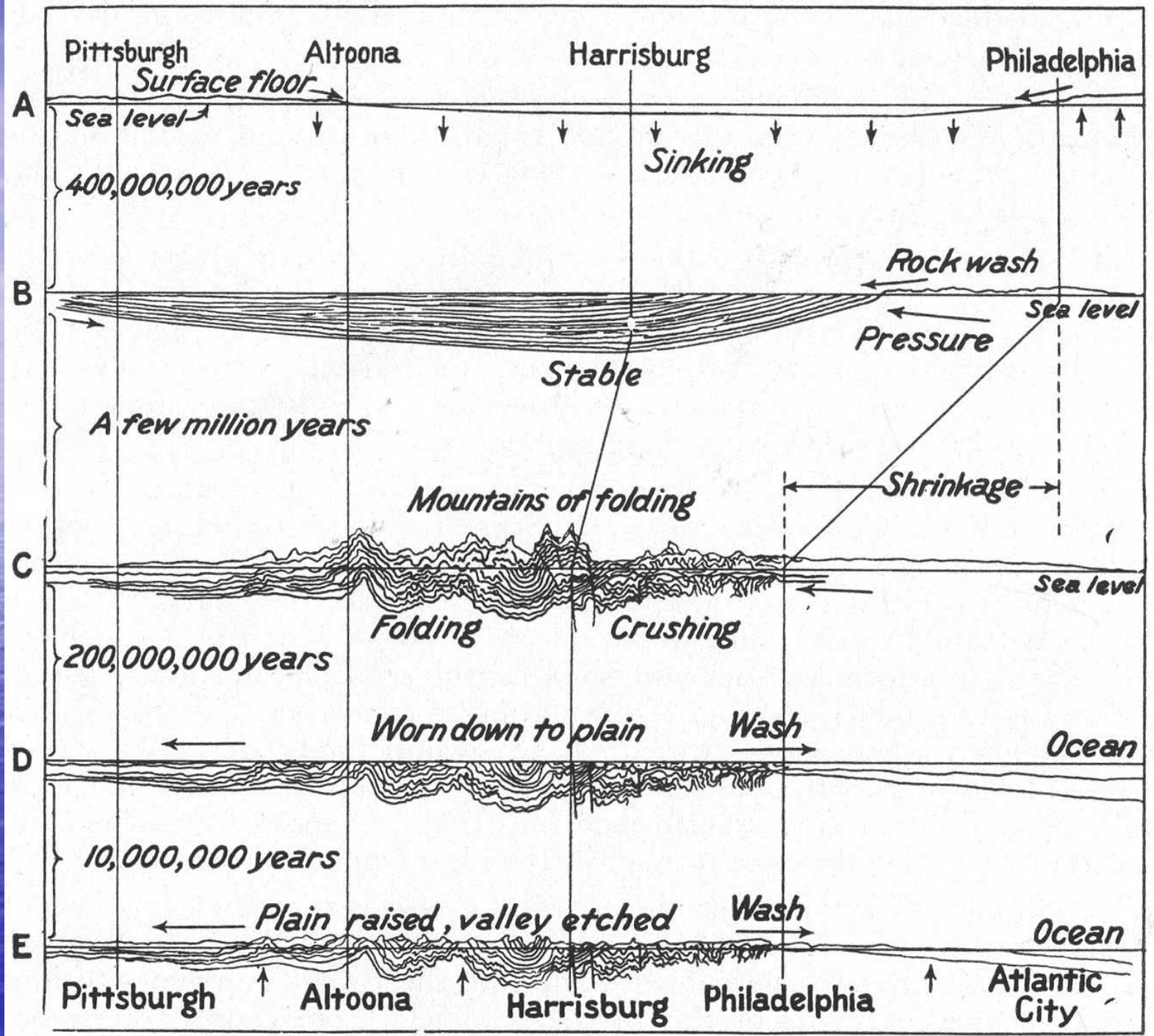
The Pennsylvania Turnpike

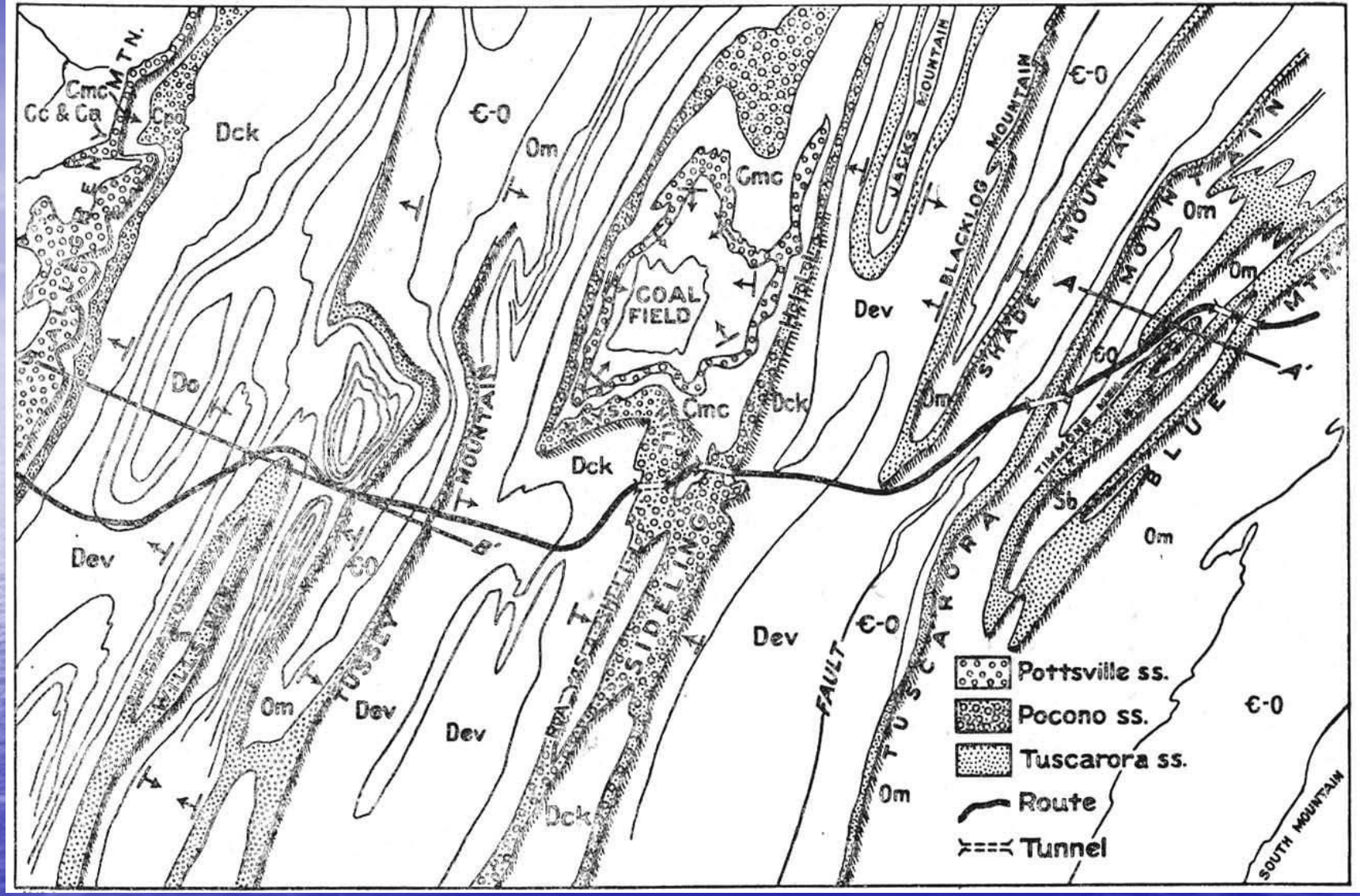
- In the late 1930s worries about another world war triggered considerations of how steel could be transported from Pittsburgh to the docks in Philadelphia

In 1937 the Pennsylvania Turnpike Commission was created by the State's General Assembly to consider the construction of a high speed highway between Pittsburgh and Philadelphia that could support heavy truck traffic.

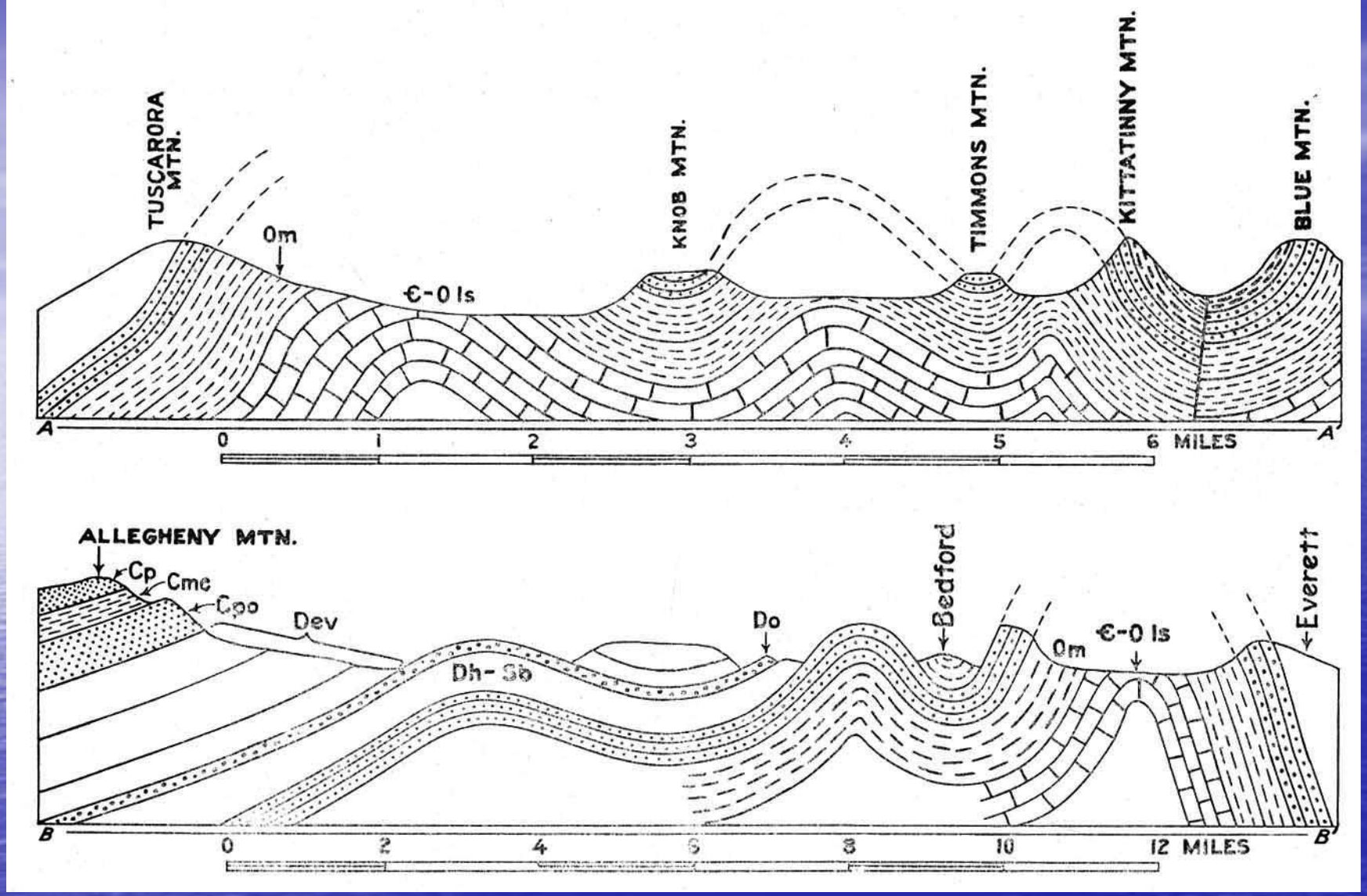
The commission decided to utilize the partly-completed South Penn Railroad alignment as a means of hastening the project, using 7 of the 9 existing tunnels. Their goal was to complete the super highway in just 20 months !


ADMINISTRATION
RIGHT-OF-WAY
Expert Witness, Claims Relative to Mineral Rights, Coal Mines, Evaluations, Litigation, Quarries, Water Wells.
PUBLICITY
Magazine Articles, Lectures, Bulletin, Final Report.
CONSTRUCTION
TUNNELS
Aggregate, Overbreak and Backpacking, Dangerous Roof Conditions, Acid Water Treatment, Geological Classification, Rock Water Supply, Roof Supports, Dust Control, Drainage, Claims.
ROADS
Water Supply, Geological Surveys, Shoulder Materials — Claims, Property Damage — Aggregate, Slide Prevention and Control — Fills, Mine Excavation and Backfill — Cuts, Erosion Control and Beautification, Geological Inspection for Maintenance, Foundations for Structures and Buildings.
EXPLORATORY
Test Pits, Coal Mines, and Subsidence, Route Location, Interpretation and Utilization of Preliminary Work, Geological Surveys, Diamond Core Borings.
ROADS
ROCK
Cut Design, Classification, Aggregate Sources, Slide Prevention and Treatment, Shoulder Material, Erosion Prevention and Beautification.
STRUCTURES
Pier and Abutment Design, Foundation.
DESIGN
TUNNELS
EXPLORATORY
Interpretation & Utilization of Borings, Underground Preliminary Studies, Geological Surveys.
GROUND WATER
Watertable, Analyses and Surveys, pH Surveys, Drainage, Action on Tunnel Lining, Supply.
ROCK
Dangerous Areas, Classification, Portal Foundations, Aggregate Sources, Dust Control.
GEOLOGY
and the
PENNSYLVANIA
TURNPIKE


Pittsburgh
Altoona
Harrisburg
Philadelphia
A
Surface floor
Sea level
Sinking
400,000,000 years
Rock wash
B
Sea level
Pressure
Stable
A few million years
Shrinkage
Mountains of folding
C
Sea level
Folding
Crushing
200,000,000 years
Worn down to plain
Wash
Ocean
D
10,000,000 years
Plain raised, valley etched
Wash
Ocean
E
Pittsburgh
Altoona
Harrisburg
Philadelphia
Atlantic City

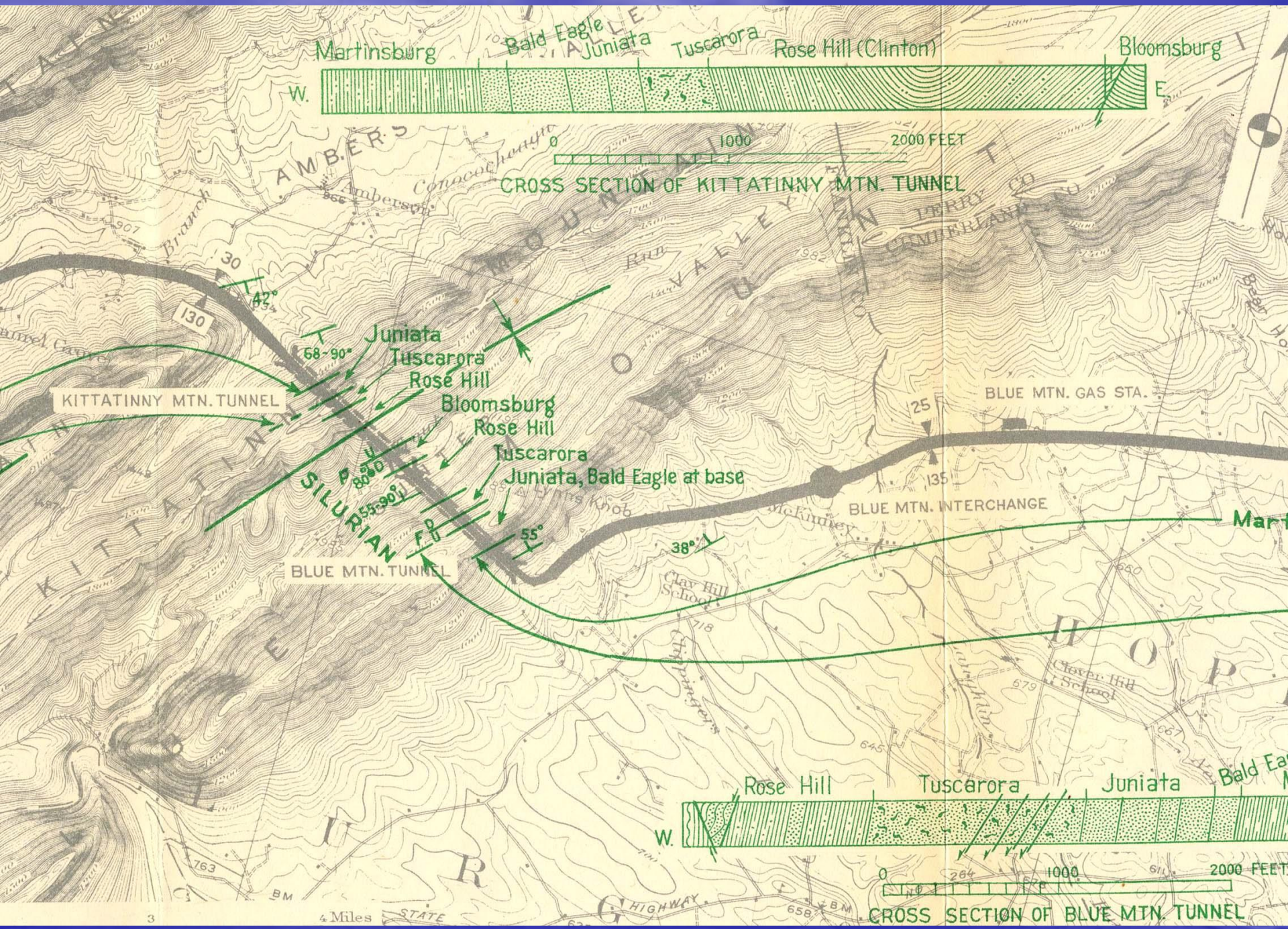


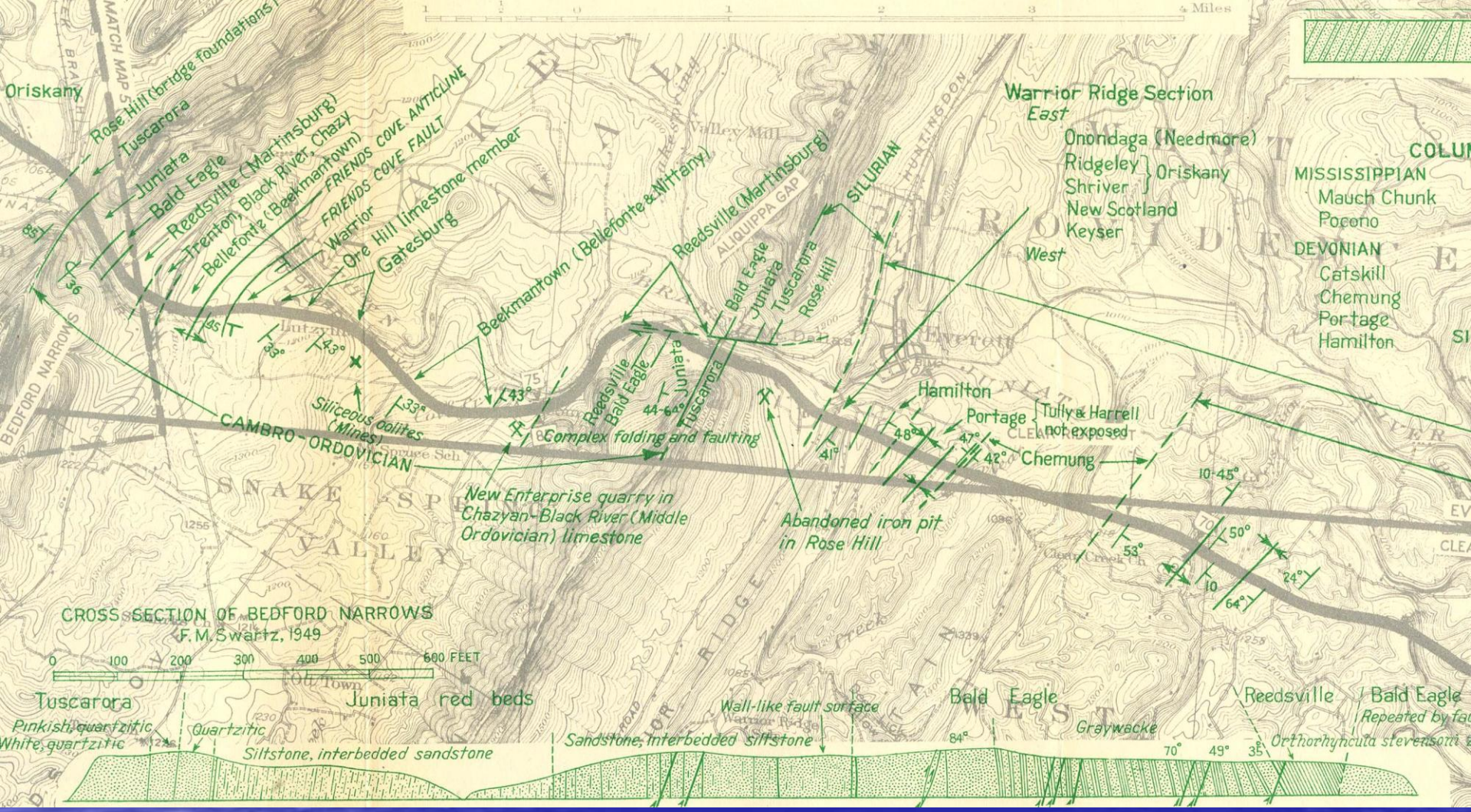
- **The old South Penn right-of-way crossed numerous coal fields and steep escarpments requiring tunnels**



- **These are some of Art Cleaves' early cross sections along the turnpike's proposed alignment**

- Cleaves began his geologic assessment in 1937 by mapping the geology inside the tunnels abandoned by the South Penn Railroad, which had been excavated 52+ years earlier.
- New tunnel alignments were explored using hollow core diamond drilling
- A horizontal hole 1450 ft long was advanced from the old Tuscarora Tunnel, a record at the time for horizontal drilling.

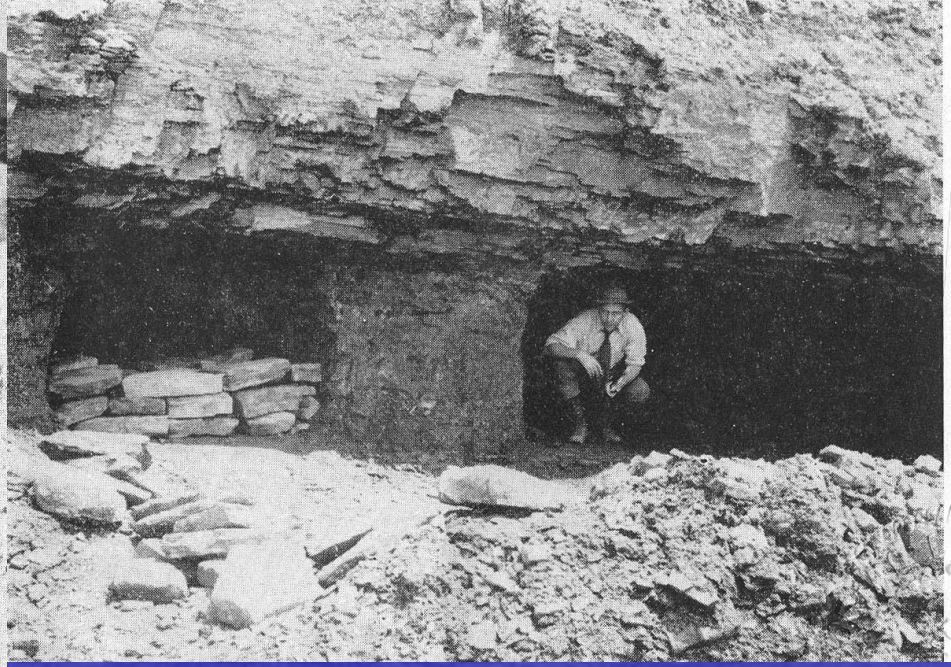

Martinsburg
Bald Eagle
Juniata
Tuscarora
Rose Hill (Clinton)
Bloomsburg
W.
E.
0
1000
2000 FEET
CROSS SECTION OF KITTATINNY MTN. TUNNEL
KITTATINNY MTN. TUNNEL
Juniata
Tuscarora
Rose Hill
Bloomsburg
Rose Hill
Tuscarora
Juniata, Bald Eagle at base
58-90°
80°
55-90°
55°
38°
42°
30
130
25
135
BLUE MTN. GAS STA.
BLUE MTN. INTERCHANGE
BLUE MTN. TUNNEL
SILURIAN
KITTATINNY
Rose Hill
Tuscarora
Juniata
Bald Ea
W.
0
1000
2000 FEET
CROSS SECTION OF BLUE MTN. TUNNEL
4 Miles
STATE
HIGHWAY



- **Geologic strip map along the Pennsylvania Turnpike where it crosses Bedford Narrows, published in the Guidebook to the Geology of the Pennsylvania Turnpike released in 1949.**

Clear Ridge Cut

- This cut was 153 ft deep and 2,475 ft long, making it the deepest cut in the eastern USA
- It exposed a thick sequence of Chemung sandstone and shale, which grade into Catskill red beds at the east end

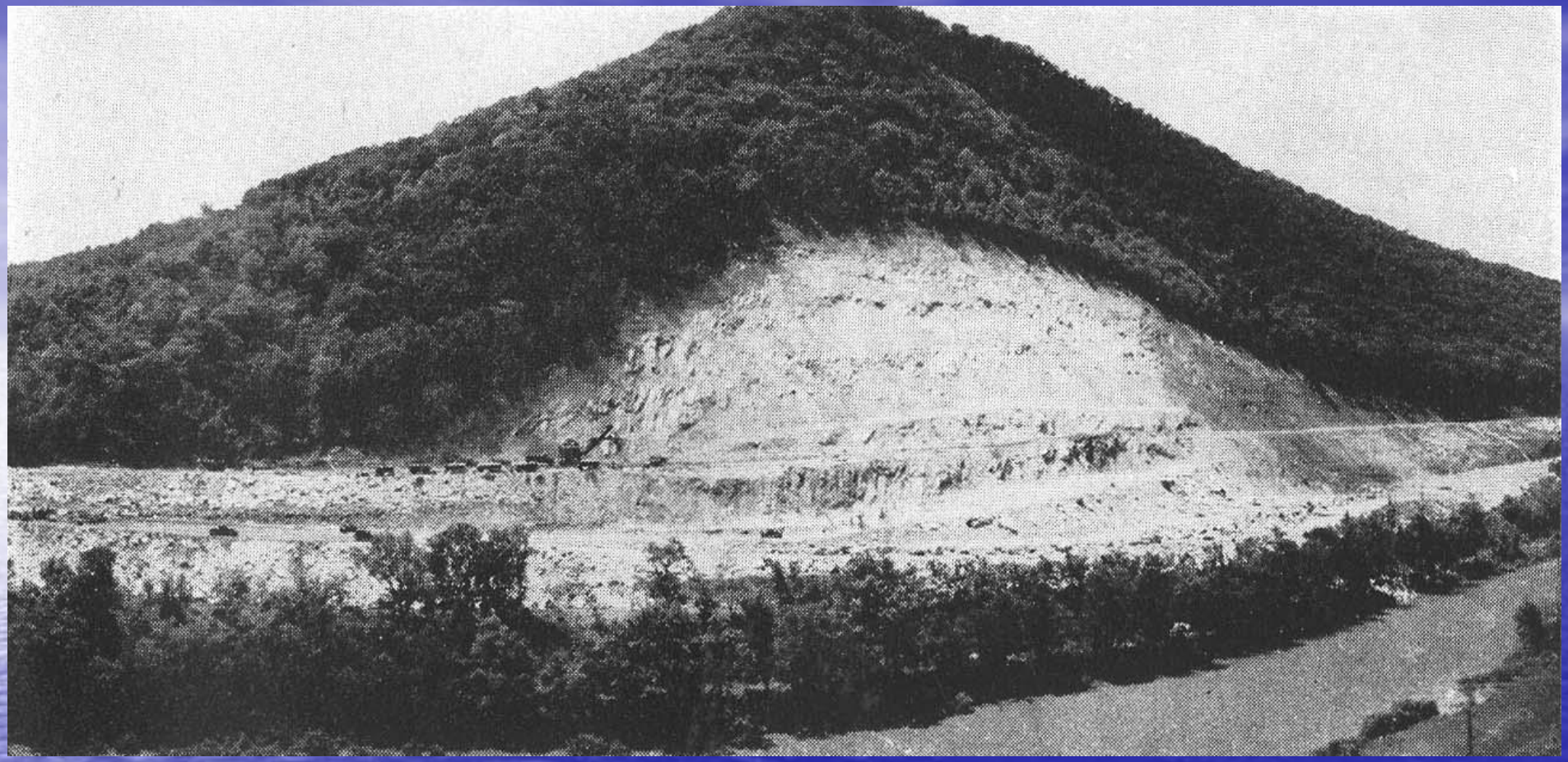


- The Upper Freeport coal measures east of the Turnpike's Laurel Hill Tunnel. Note tar-coated cmp drain pipes at lower left of left photo.
- Close-up view of the mined out coal seam, showing its thickness an character. These rooms were backfilled with stacked rock where the alignment passed them.

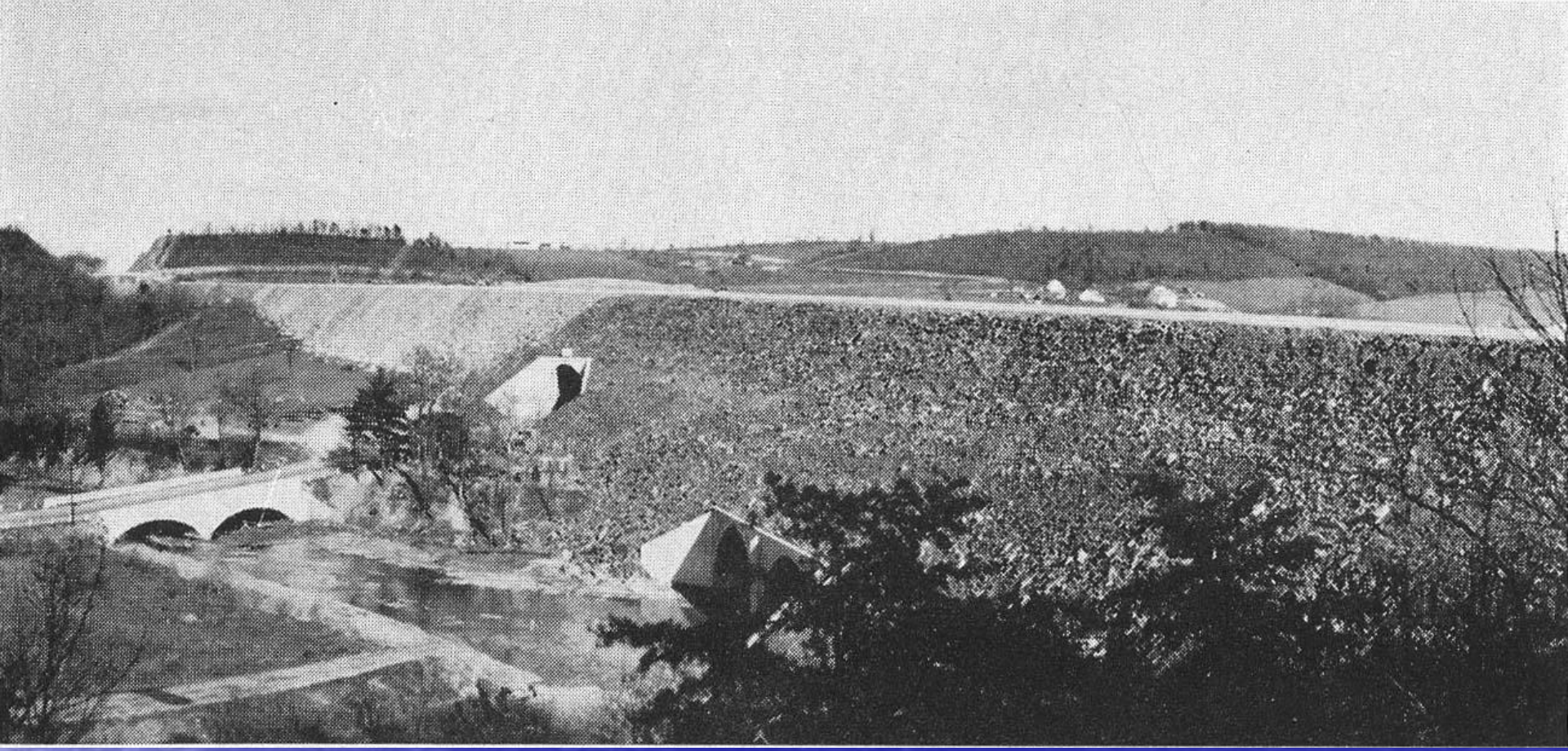
- Interbedded Catskill sandstone with interbeds of thin shale exposed in west portal of the Rays Hill Tunnel.

- West Portal of the Rays Hill Tunnel in the Catskill red beds, as completed. The ridge in background is underlain by the Pocono sandstone.

- The Arona Landslide developed in a cut made in the Conemaugh formation. Vertical joints played a role in controlling the orientation of the crown scarp.



- The Mt. Dallas Cut across Raystown Branch, seen from the south, near Everett.
- Tussey Mountain is structurally controlled by steeply east-dipping sandstone and quartzite of the Tuscarora formation, which are more resistant than the limestones to the west and shales to the east



- Rock fill embankment 98 feet high supporting the Pennsylvania Turnpike, west of the Clear Ridge Cut. Note massive reinforced concrete culvert structures carrying the local stream and tunnel for secondary highway crossing.

- The turnpike was completed in 1940, just 20 months after construction began.
- It was heralded as one of the great achievements of that time, and served as a model for the Interstate Highway program 20 years later

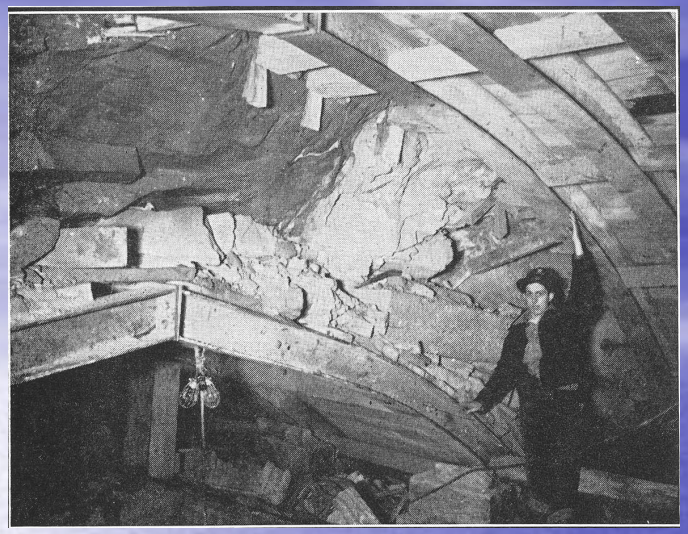
World War II

- **Between 1940-46 he worked on a series of applied geology problems associated with highways, dams, airfields, and tunnels, including service with the Office of Scientific Research & Development during the Second World War in the Solomon Islands, Hawaii, California, and Florida.**

- In 1946, Dr. Cleaves joined the faculty at Washington University in St. Louis as an Associate Professor of Geological Engineering. Promoted to full professor in 1949 and remained there until retiring in 1974.
- Terry West enrolled at Wash U's geology program in 1954 thru 1958.
- Image at left shows Professor Cleaves inspecting drilling of caissons for the new Earth and Planetary Sciences Building under construction in 1969

Terry and Shirley West, shortly after their marriage in 1957, while he was attending Wash U in St. Louis.

- Terry West enrolled in geology at Washington University in St. Louis in the fall of 1954.
- He received his B.S. in geological engineering and A.B. in geology concurrently, in 1959.
- From 1959-61 he worked with Professor Art Cleaves on an M.A. degree in geology, with a minor in civil engineering.

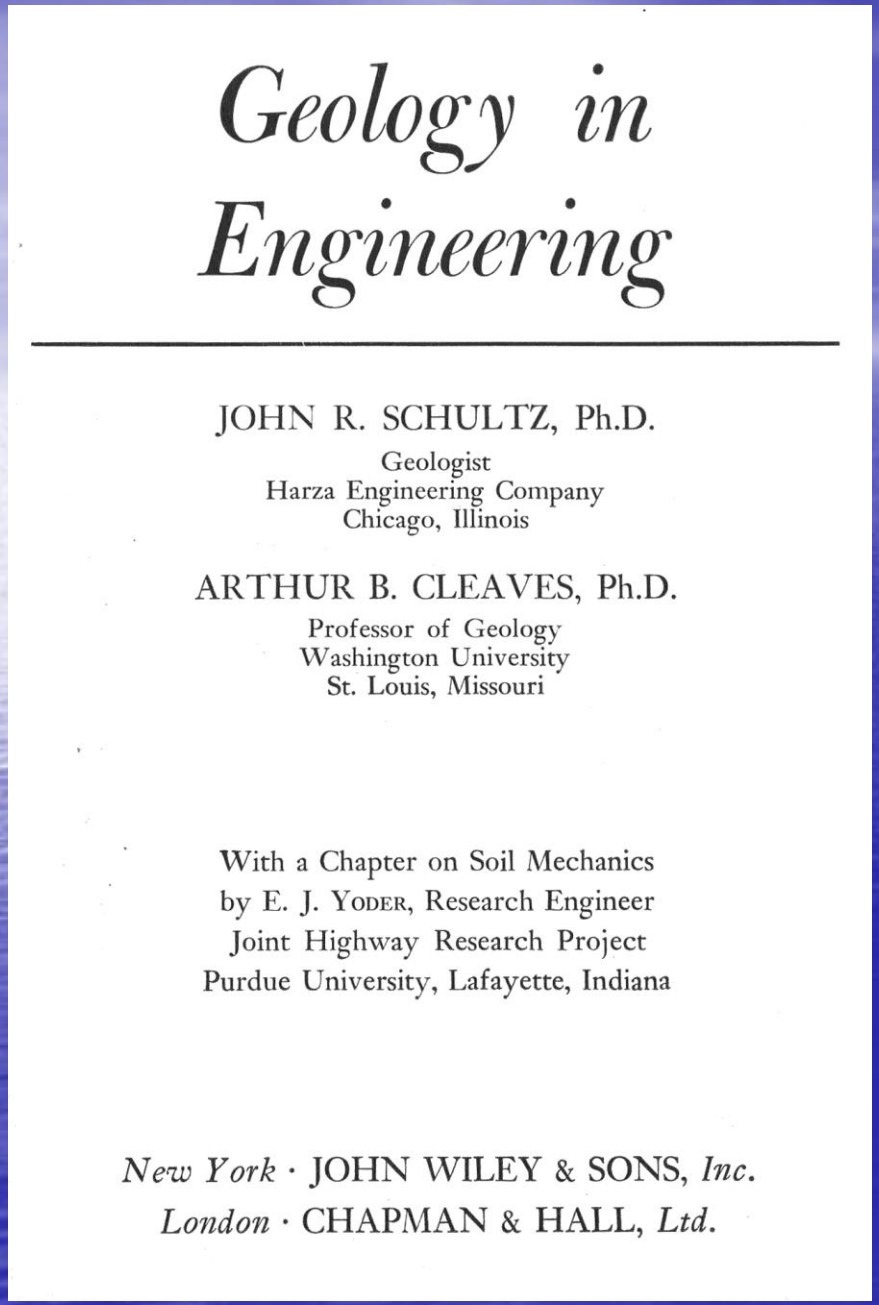


Engineering Geology Division of GSA

- Art Cleaves was a key figure in the establishment of the Engineering Geology Division of the Geological Society of America in 1947
- He co-authored the division's bylaws and serving on the Committee for Teaching Aids and on that for Publications.
- He prepared a chapter in the 1950 text "Applied Sedimentation," one of the early seminal works in applied geology.
- Soon thereafter Cleaves was named chair of the EGD committee examining the "Influence of Geological Factors on Tunnel Construction," and served as the EGD chairman in 1953

Sought for consultations

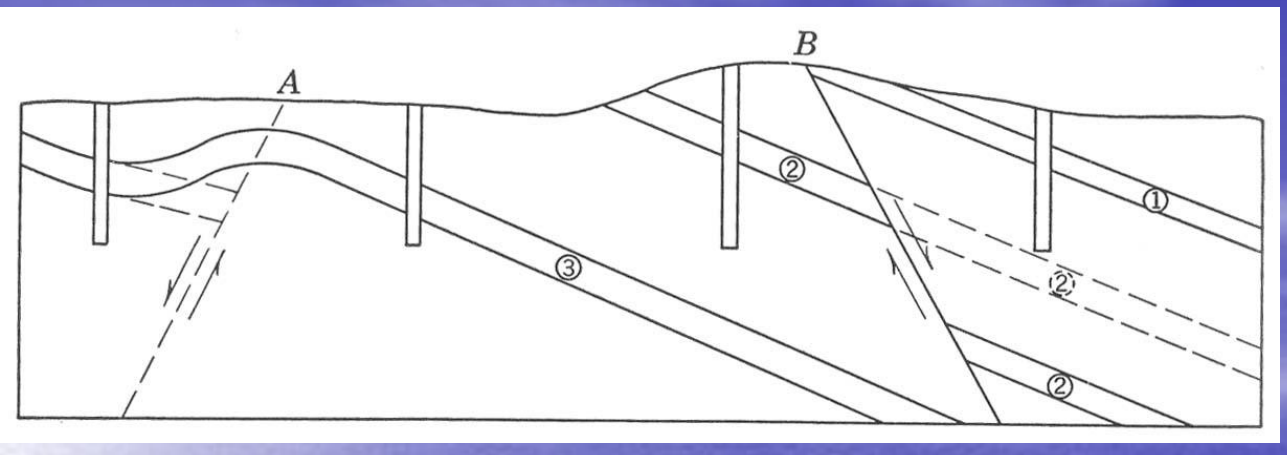
- Left: Flowing ground coming into the working face of the Kittatinny Tunnel on the Pennsylvania Turnpike. Right: Roof failure in the West Allegheny Tunnel in the late 1940s
- Cleaves also consulted on numerous dam sites, mines, missile silos and oil wells all over the United States , Venezuela, Lebanon, and Italy.

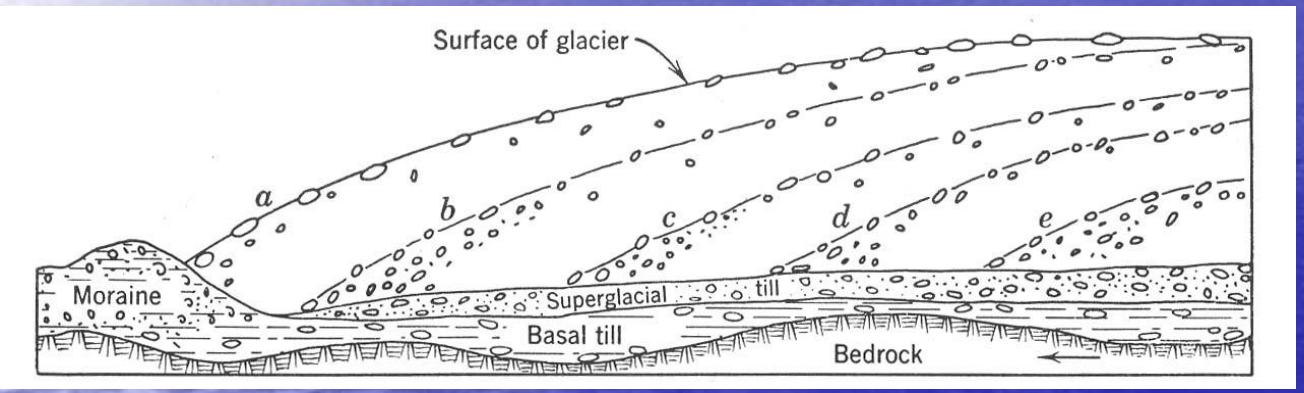


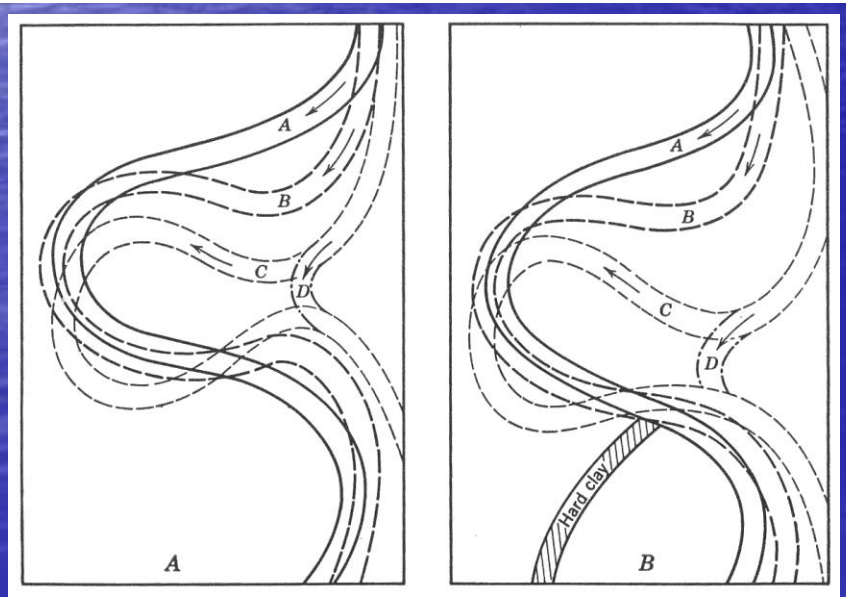
Geology in Engineering

- In the early 1950s Cleaves collaborated with John R. Schultz, chief geologist with Harza Engineering Co. of Chicago, and E. J. Yoder, a research engineer at Purdue, to write the text "Geology in Engineering." It was published by John Wiley in 1955 and remained in print for over a decade.

Figures from *Geology in Engineering*

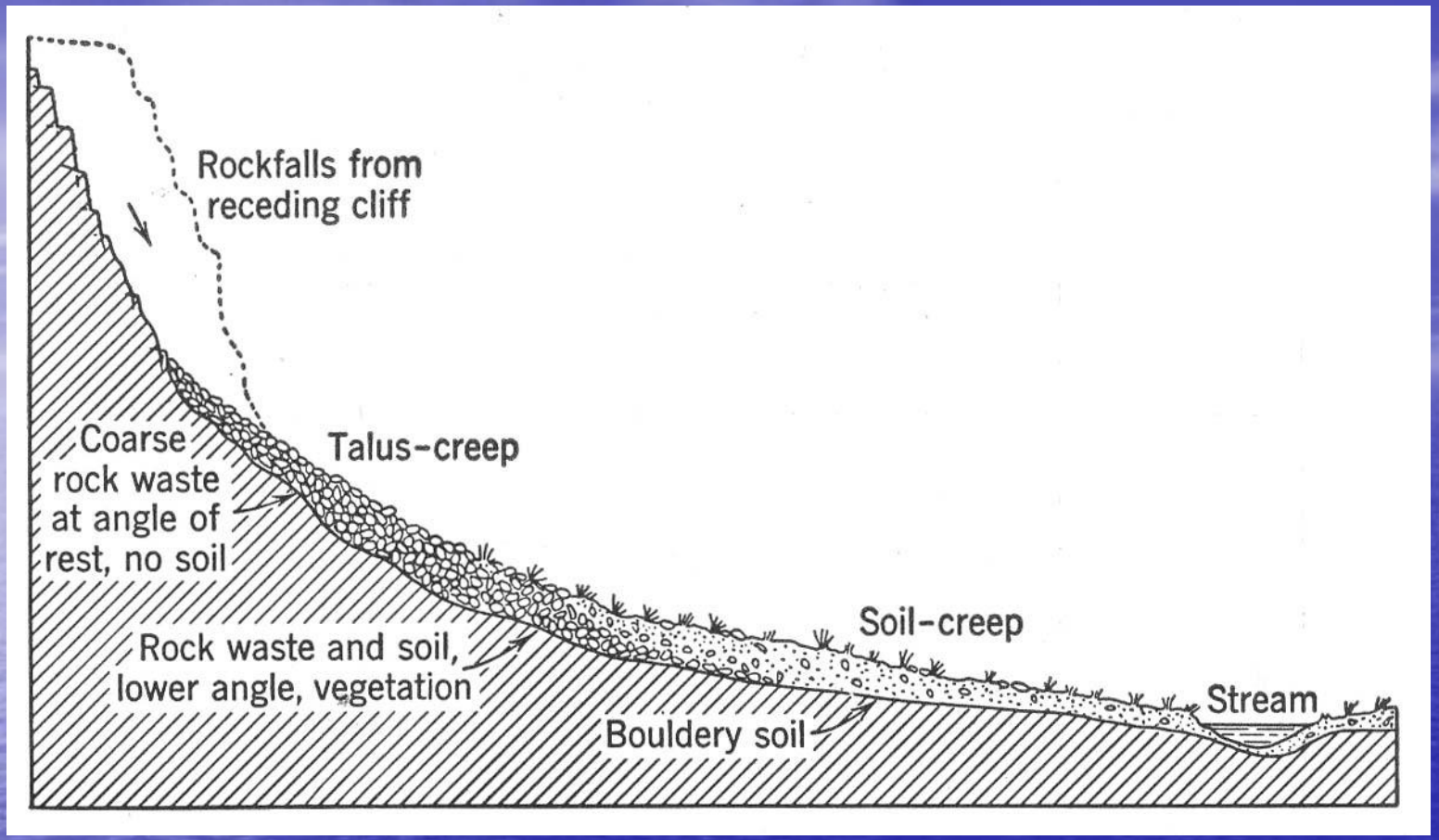




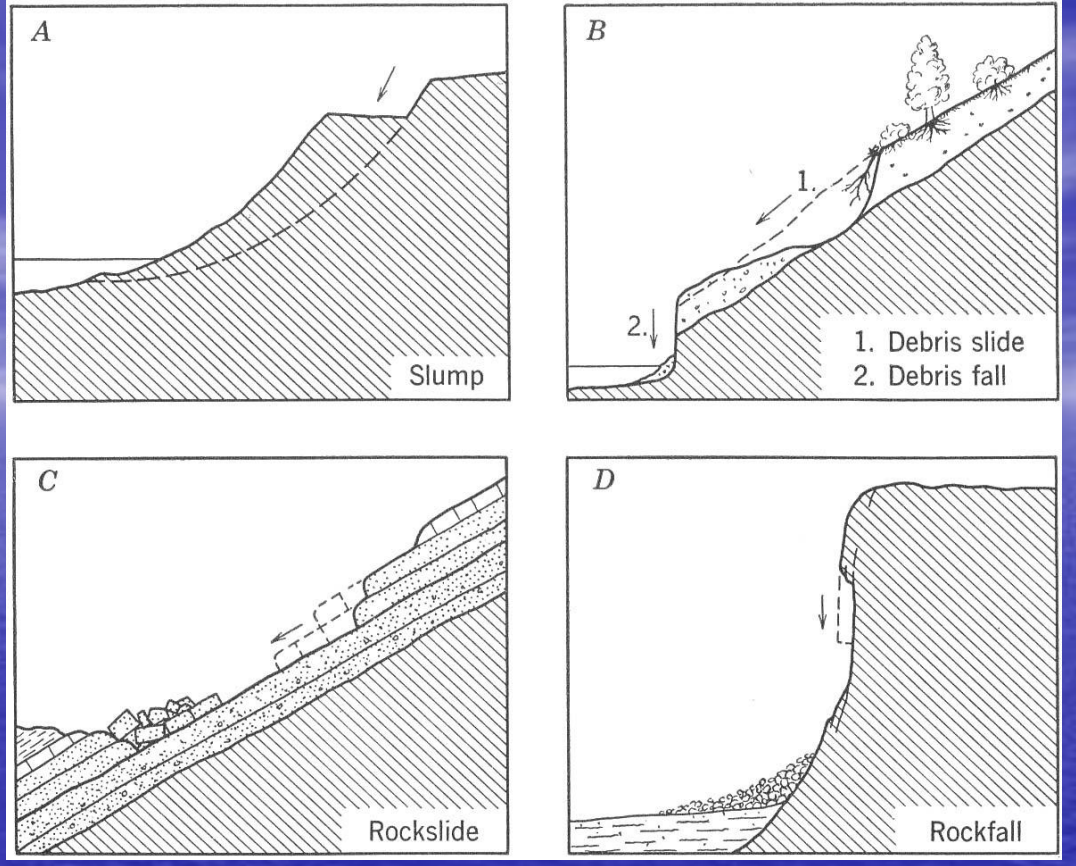


Most of the figures in the textbook were based on the author's personal experience

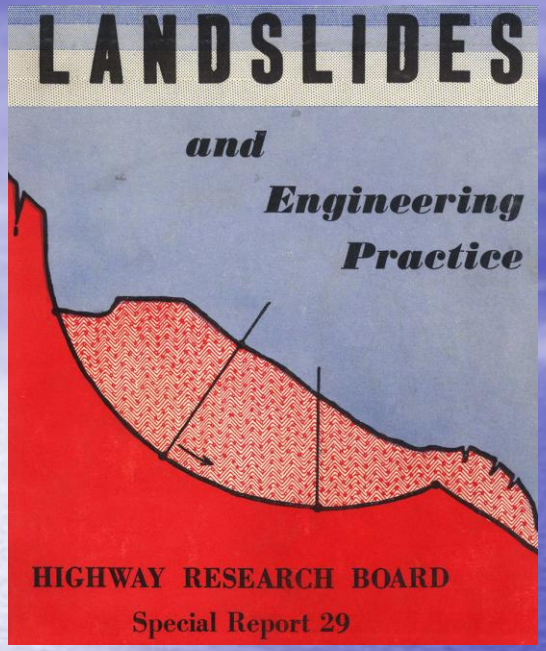
The cross section at upper left is just as important today as it was back in 1955, illustrating the potential pitfalls of liner interpolations between adjacent boreholes.



- **Simple hypothetical section through a retreating escarpment, showing the natural particle sorting that occurs with increasing offset from the receding cliff face. Where is the demarcation between "slide debris" and "soil"?**



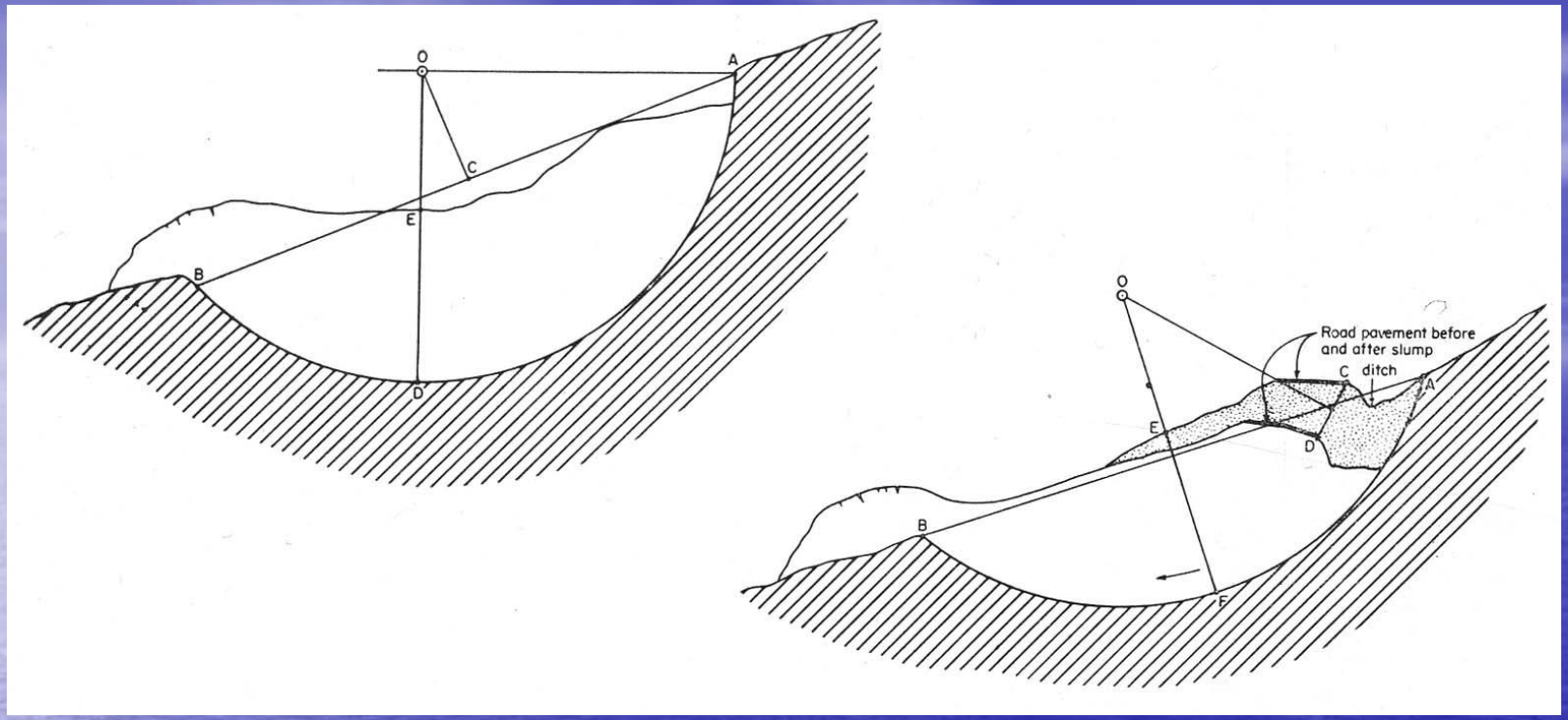
- The textbook was released three years before Varne's now famous classification scheme, in HRB SR29.
- In these sketches Schultz and Cleaves tried to illustrate the different kinds of slope failures.
- The example at upper left is from the Ozarks in Missouri, in highly overconsolidated weathered residum.



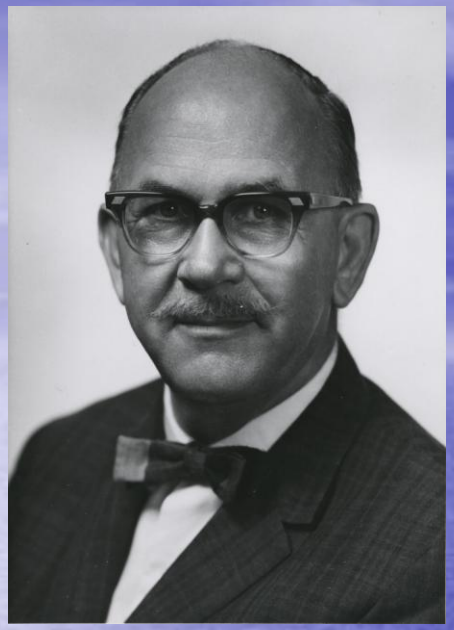
HRB Special Report 29

By the mid 1950s Cleaves was also serving as chairman of the Committee on Landslide Investigations of the Highway Research Board.

- This interest grew out of his work with the Pennsylvania Turnpike, which continued each summer, between terms.
- In 1958 he and Shailer Philbrick co-authored the chapter "Field and Laboratory Investigations" for HRB Special Publication 29, Landslides in Engineering Practice, which became the standard work on the subject for the next two decades.



- One of the more useful contributions of his chapter in HRB SR29 were these graphical methods for estimating the maximum depth of slippage of a slump landslide, which have been in general use over the past 50 years.

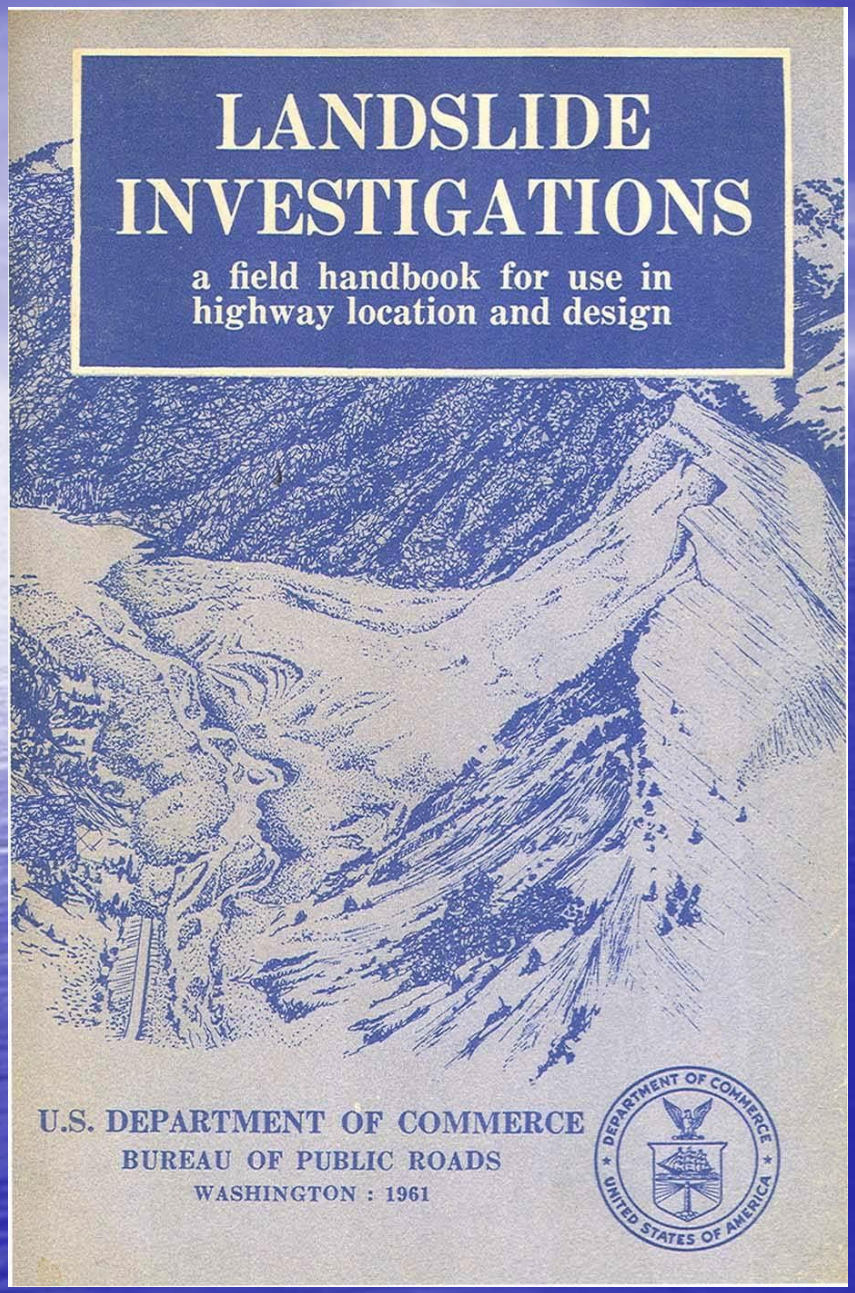


Cleaves

Legget

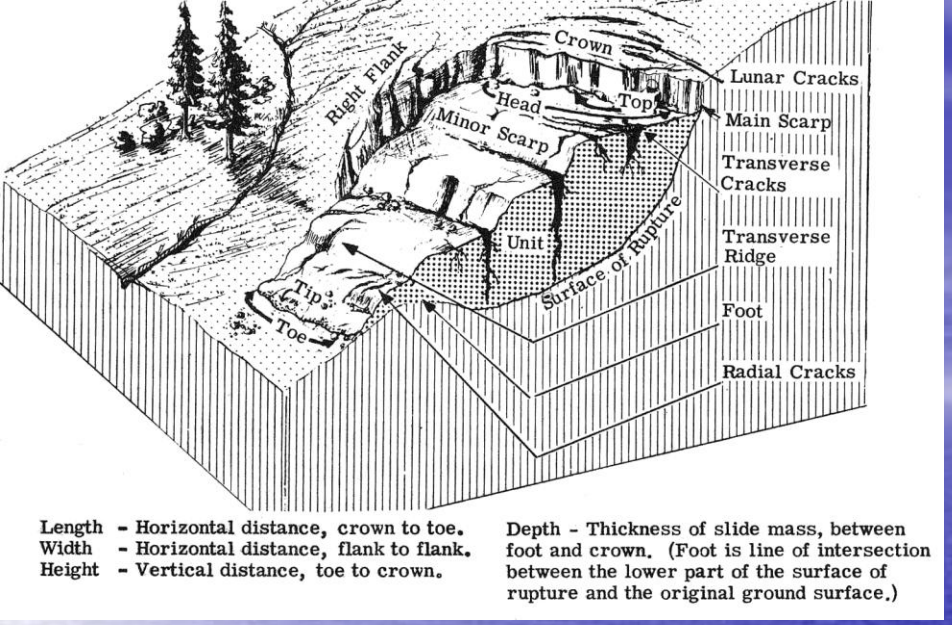
Kiersch

- At the 1958 GSA annual meeting in St. Louis, Professor Cleaves arranged a televised panel discussion on influence of geohazards, such as landslides along the Mississippi River terraces in the St. Louis area, comprised of himself, Robert Legget, and George Kiersch. This panel discussion focused considerable attention on the importance of engineering geology.
- Shortly afterwards, he became a registered professional engineer in Missouri, and achieved fellow member status in GSA, ASCE, and NSPE.



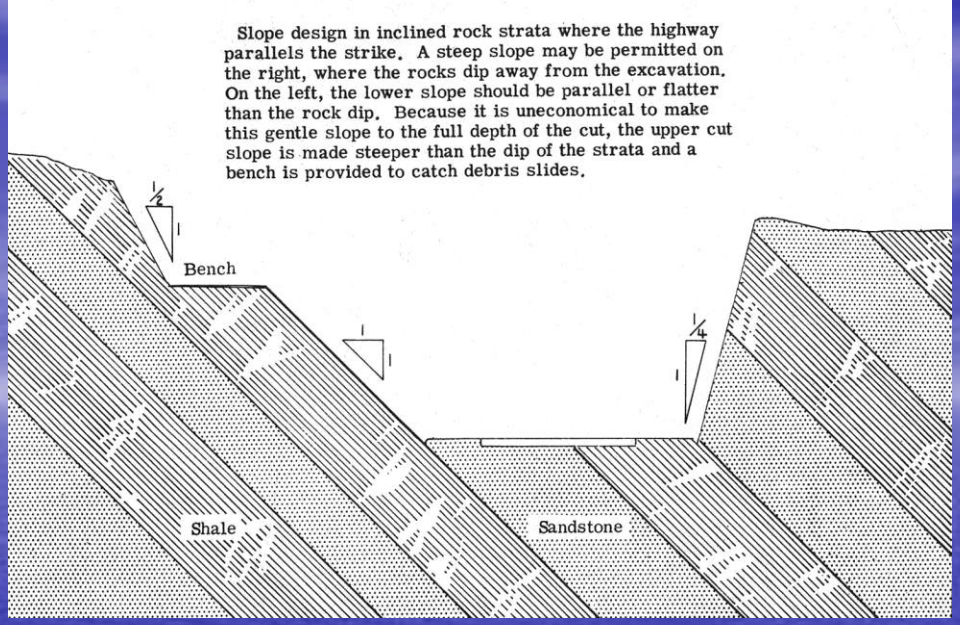
Landslide Investigation Handbook

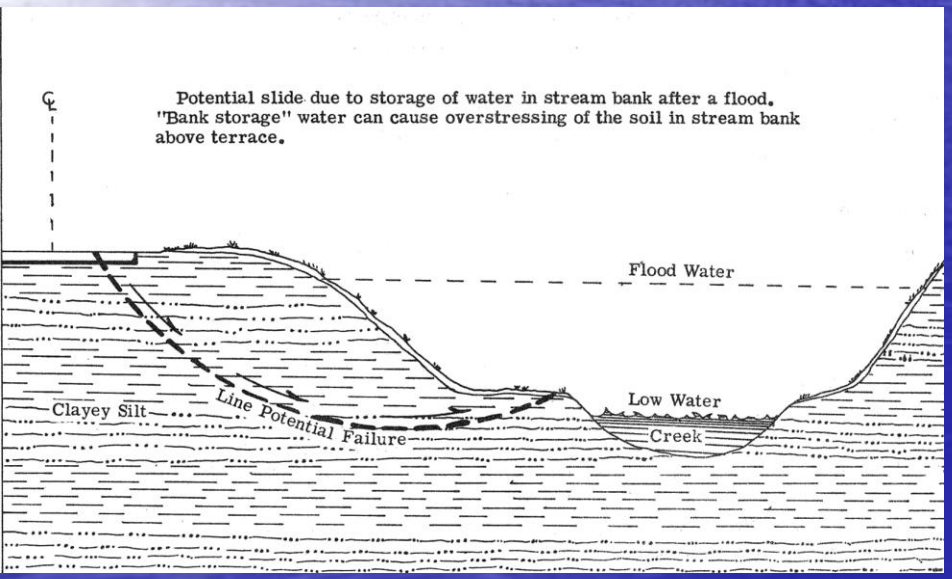
- In 1961 Professor Cleaves prepared the "*Landslide Investigations: A Field Handbook for use in Highway Location and Design*," published by the U.S. Bureau of Public Roads.

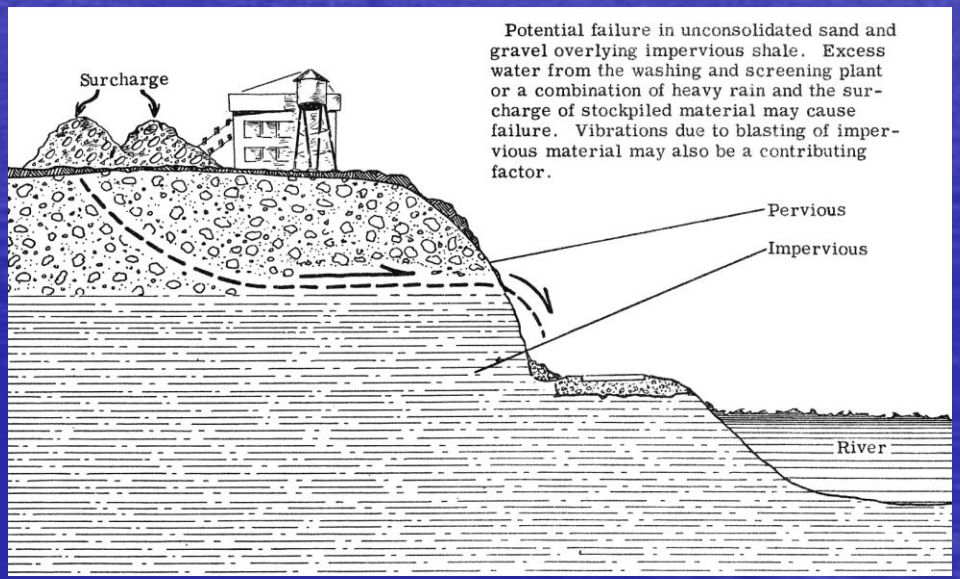


Length - Horizontal distance, crown to toe.
Width - Horizontal distance, flank to flank.
Height - Vertical distance, toe to crown.

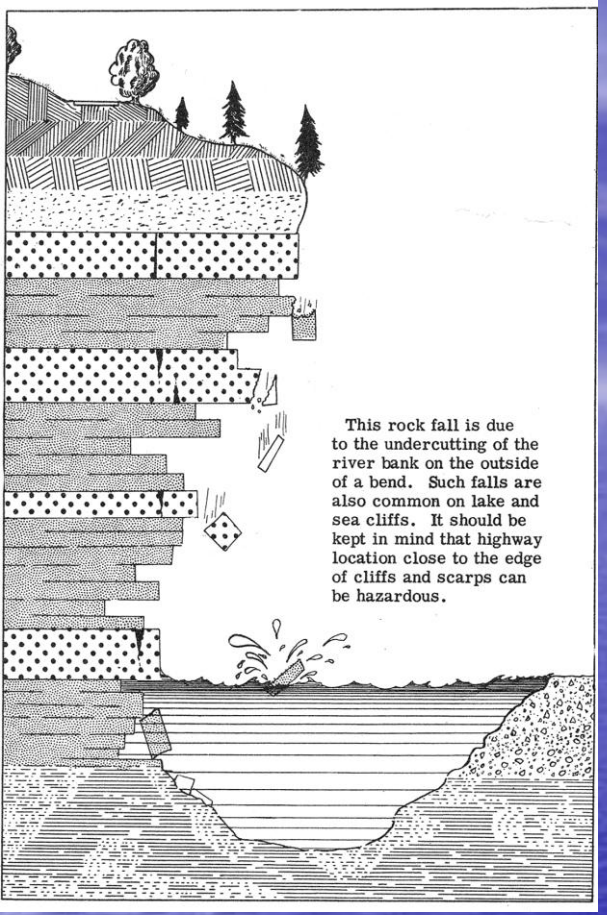
Depth - Thickness of slide mass, between foot and crown. (Foot is line of intersection between the lower part of the surface of rupture and the original ground surface.)

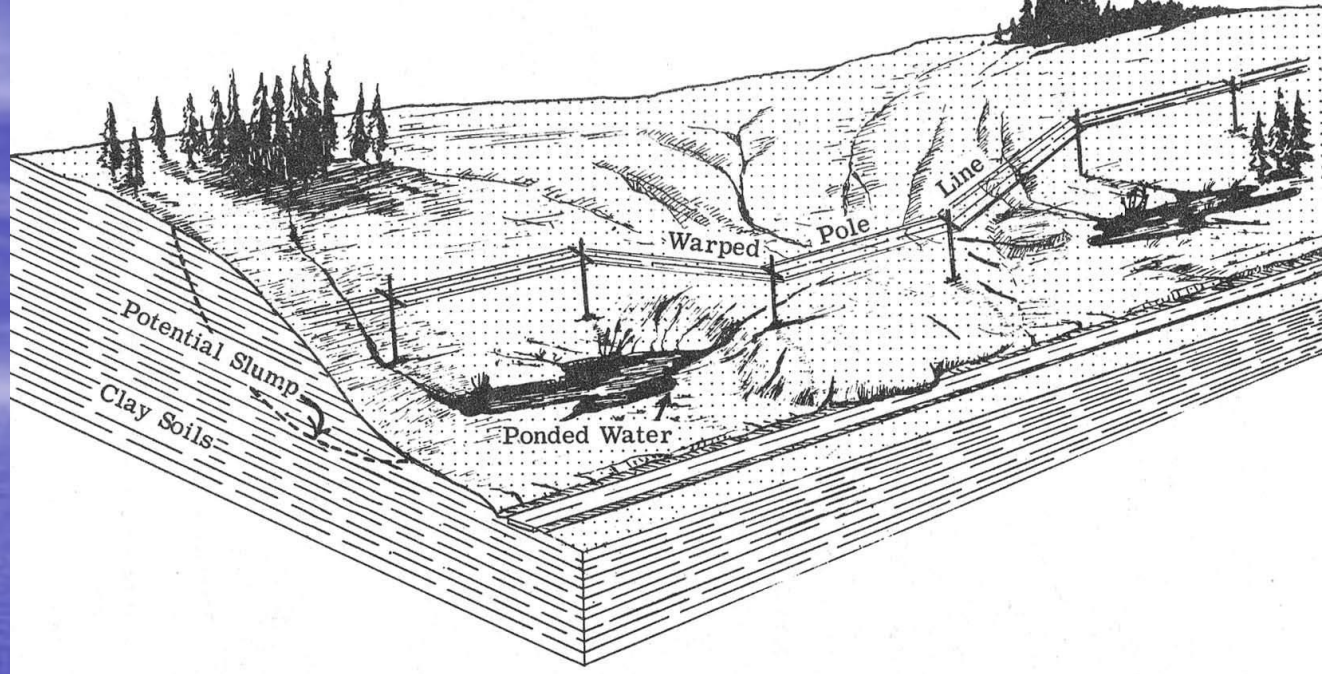




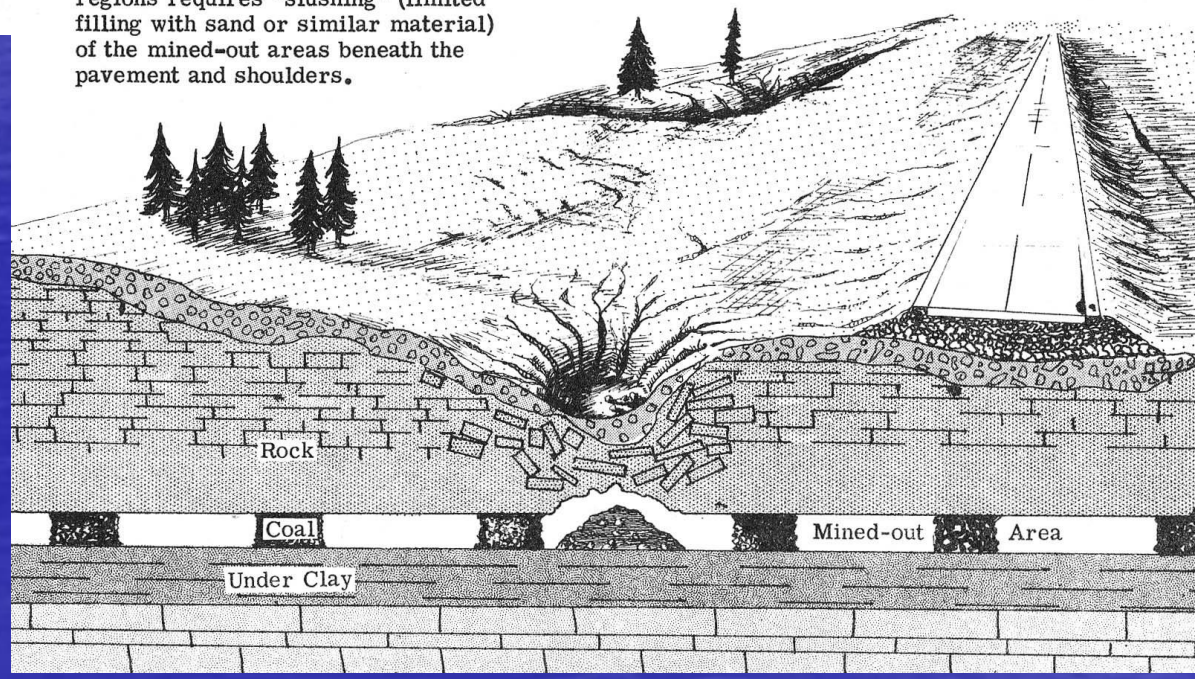


Figures from Cleaves' 1961 field handbook, showing landslide nomenclature, highway cuts, rapid drawdown conditions, and perched groundwater impacts.

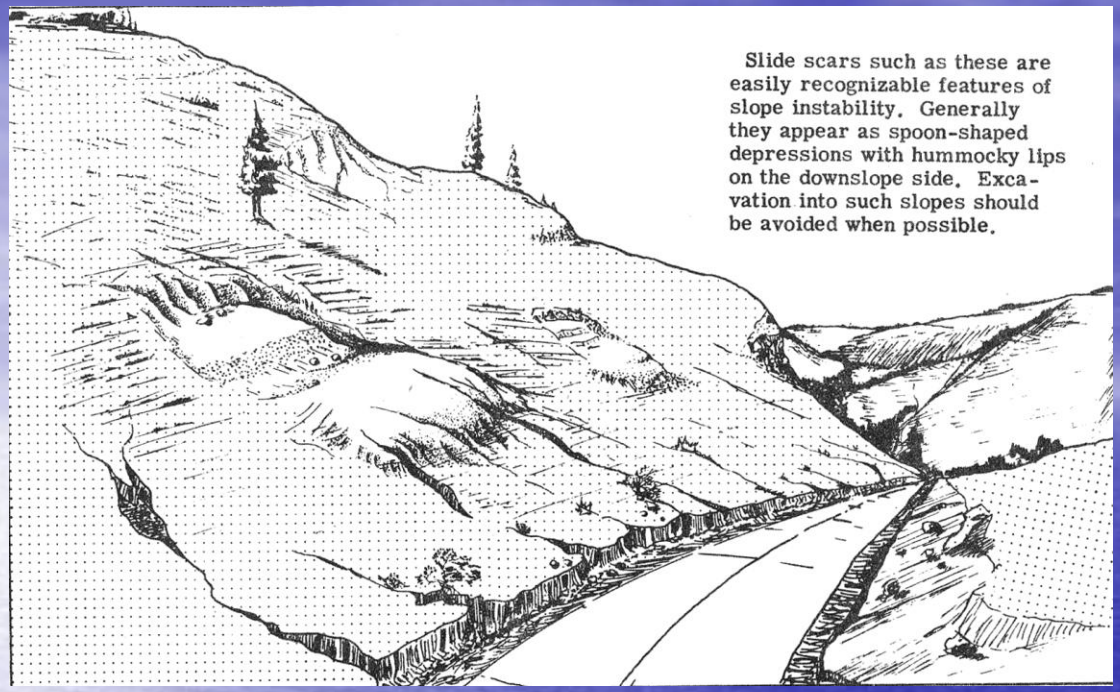




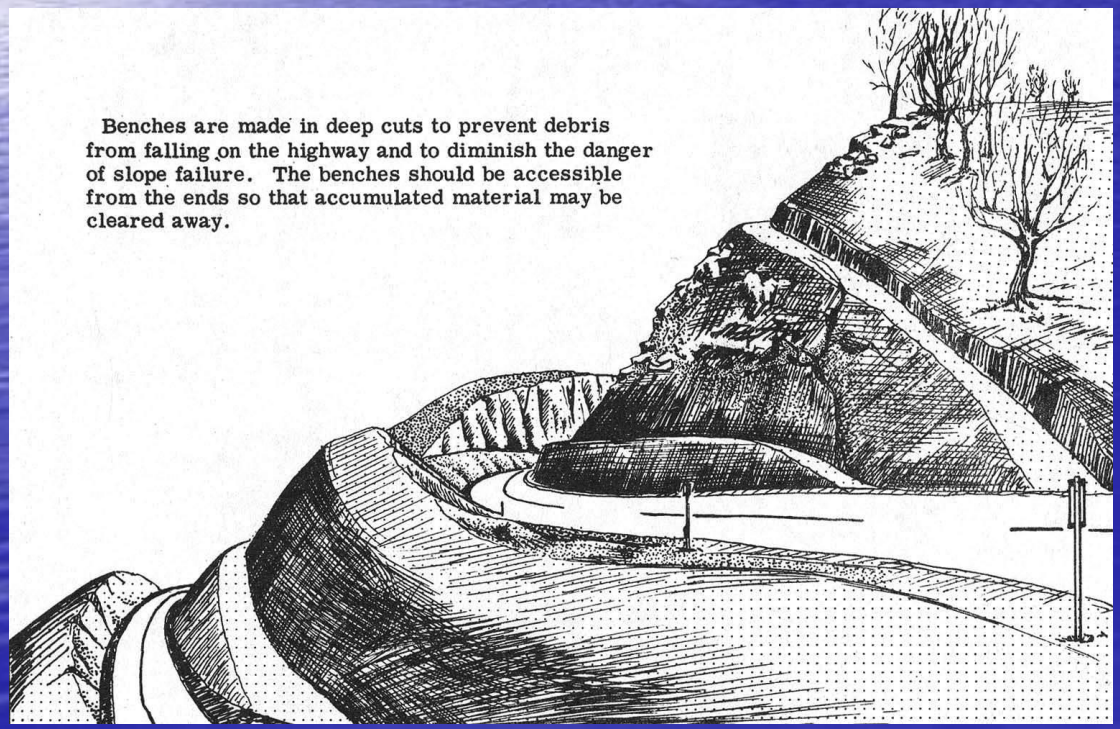
Creep is the slow, imperceptible movement of soil downslope. Here the offset



Sections and block diagram illustrating bank undercutting, slope creep, and mine collapse, and/or subsidence.

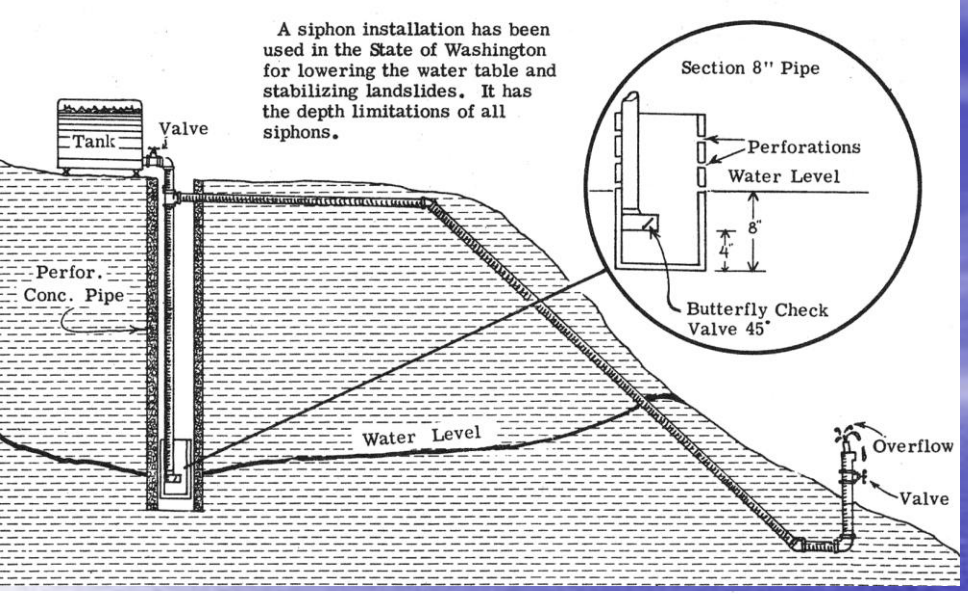


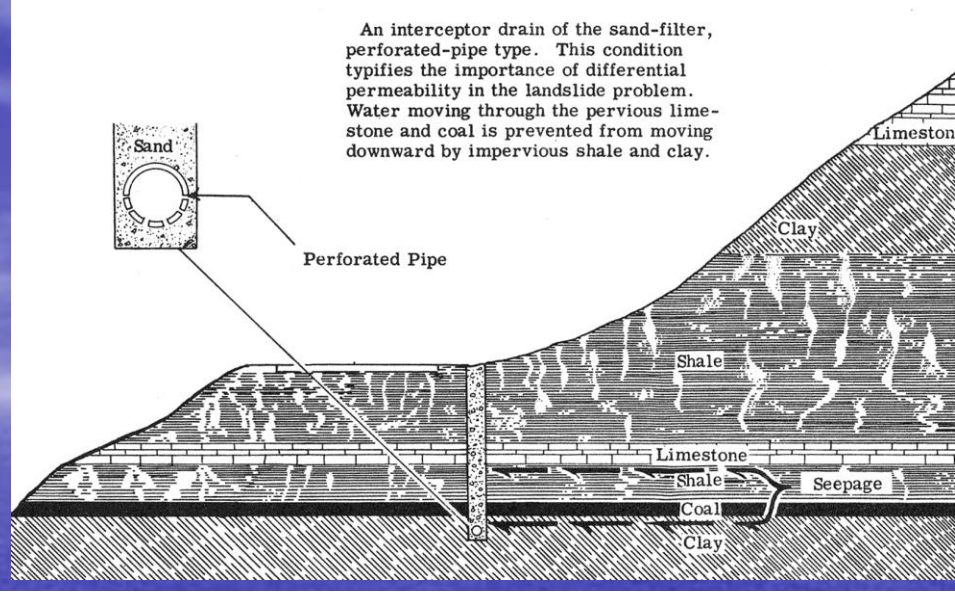
Slide scars such as these are easily recognizable features of slope instability. Generally they appear as spoon-shaped depressions with hummocky lips on the downslope side. Excavation into such slopes should be avoided when possible.

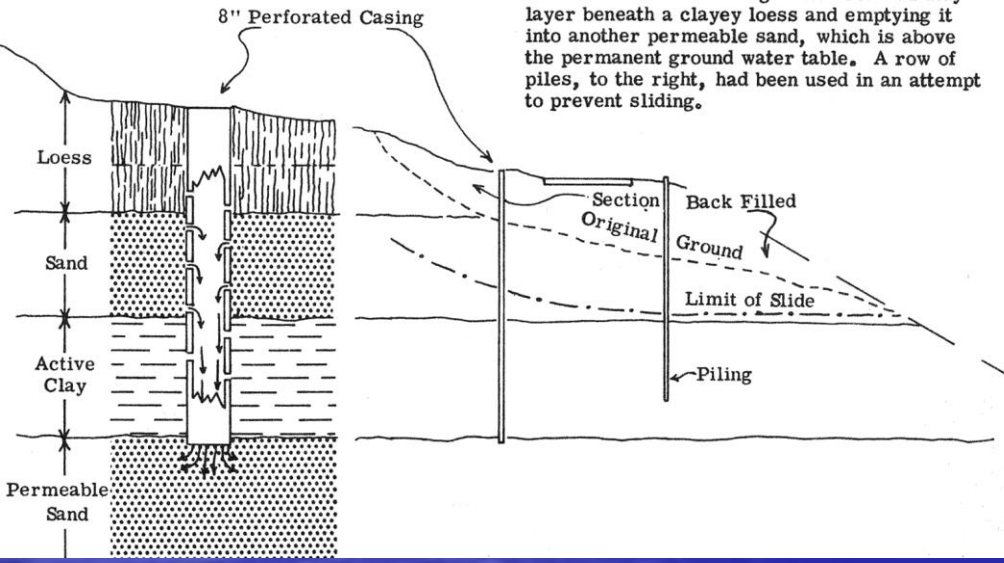


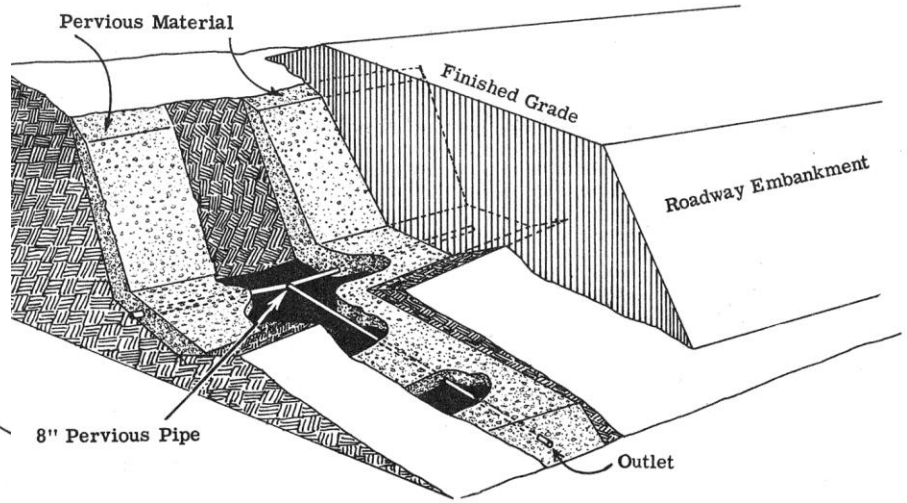
Benches are made in deep cuts to prevent debris from falling on the highway and to diminish the danger of slope failure. The benches should be accessible from the ends so that accumulated material may be cleared away.

The 1961 handbook also emphasized remedial measures for troubled cut slopes, as pictured here.



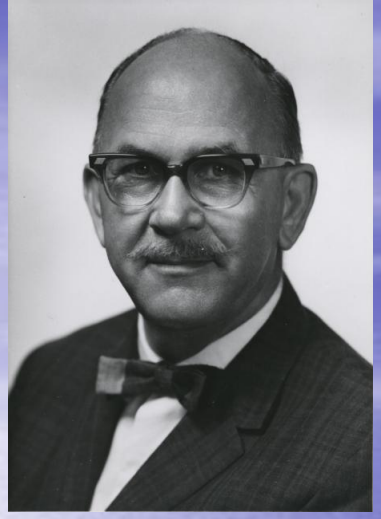






Use of interceptor trench, pervious blanket and perforated-pipe drains to stabilize foundation for sidehill fill on portion of Dunsmuir Freeway, U.S. Hwy. 99, Northern California. Bottom of longitudinal trench, outlet trench, and upslope side of trench have 3 ft. blanket of gravel.

Graphical depictions of various drainage stabilization schemes that had been employed along highways prior to 1961.



National Research Council Committee service

- In February 1962 Professor Cleaves was named chairman of a nine-member committee on Slope Stability and Erosion Control set up by the Building Research Advisory Board of the National Research Council and National Academy of Sciences.
- The committee included member with backgrounds in engineering geology, soil mechanics, soil agronomy, landscaping and planting, construction and sanitary engineering to focus on slope stability and erosion problems.
- The committee was charged with providing the FHA with the most up-to-date information which would lead to more responsible construction practices in the residential housing industry.

Close of an Active Career & Retirement

- In 1969 he and George Kiersch co-edited "*Legal Aspects of Geology in Engineering Practice*," contained in Engineering Geology Case Histories No 7.
- In 1971 the Wash U geology program was re-designated as the Dept. of Earth & Planetary Sciences, a few years before Cleaves retired in 1974.

Retirement Years

- Shortly after retiring in May 1974, he was named to the U.S. National Committee on Tunneling Technology of the National Research Council.
- He remained an active consultant on a wide range of projects, and maintained his residence in St. Louis.
- His wife Kathryn died in February 1983, at age 73
- Two years later, Professor Cleaves died of a brief illness while visiting his son Emery in Baltimore on June 6, 1985, at age 79.
- Son Dr. Emery T. Cleaves served as Director of the Maryland Geological Survey from 1993-2007

This lecture will be posted at

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in .pdf format for easy downloading and use by others.