GEL2150: Field course and methodology in geology and geophysics

Introduction to exercise

Geophysical Part

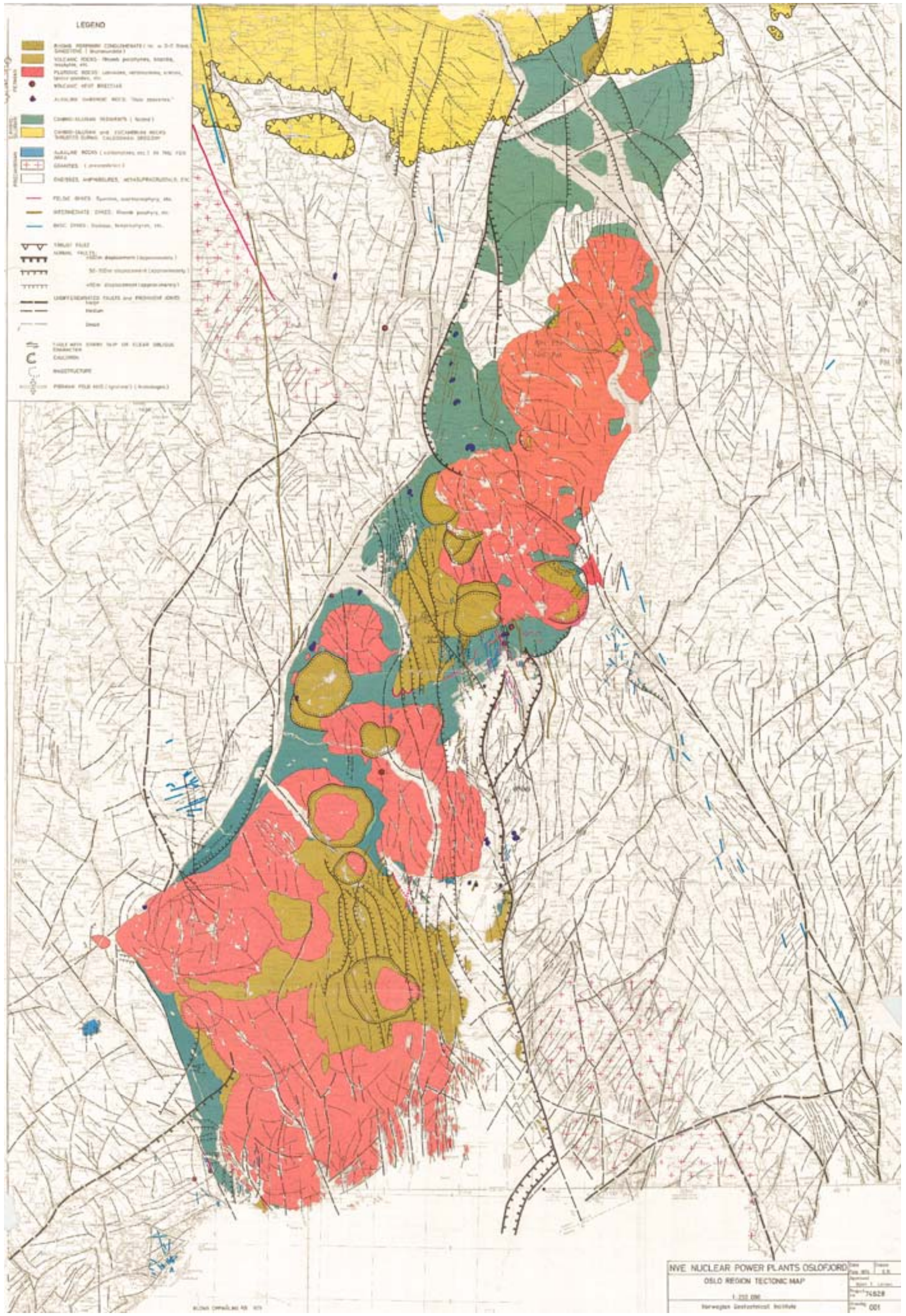
Objective

- Introduction to seismic interpretation
- Introduction to interpretation of potential field data

- In the field, impression of seismic principle and scale in comparison to the real geology

Contents of this lecture

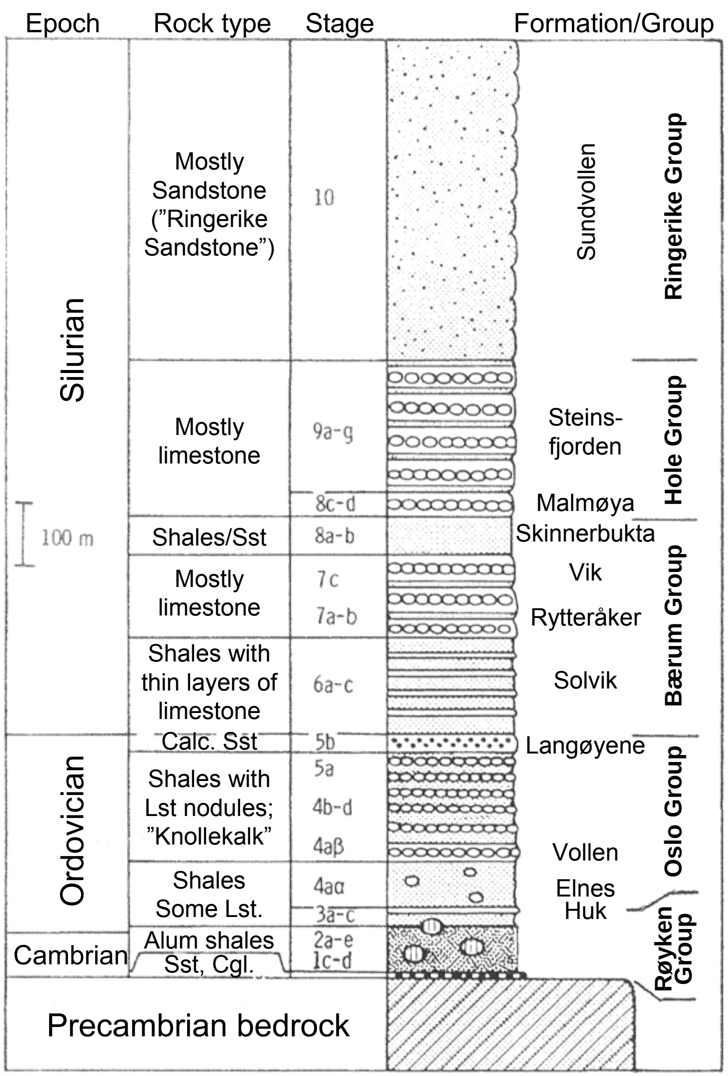
- Geology of the Oslo Rift (Oslo + Skagerrak grabens)
- Stratigraphic logging in the field
- Synthetic seismograms
- Introduction to determination of acoustic impedance in the field
- Correlation between stratigraphy and seismic
- Report



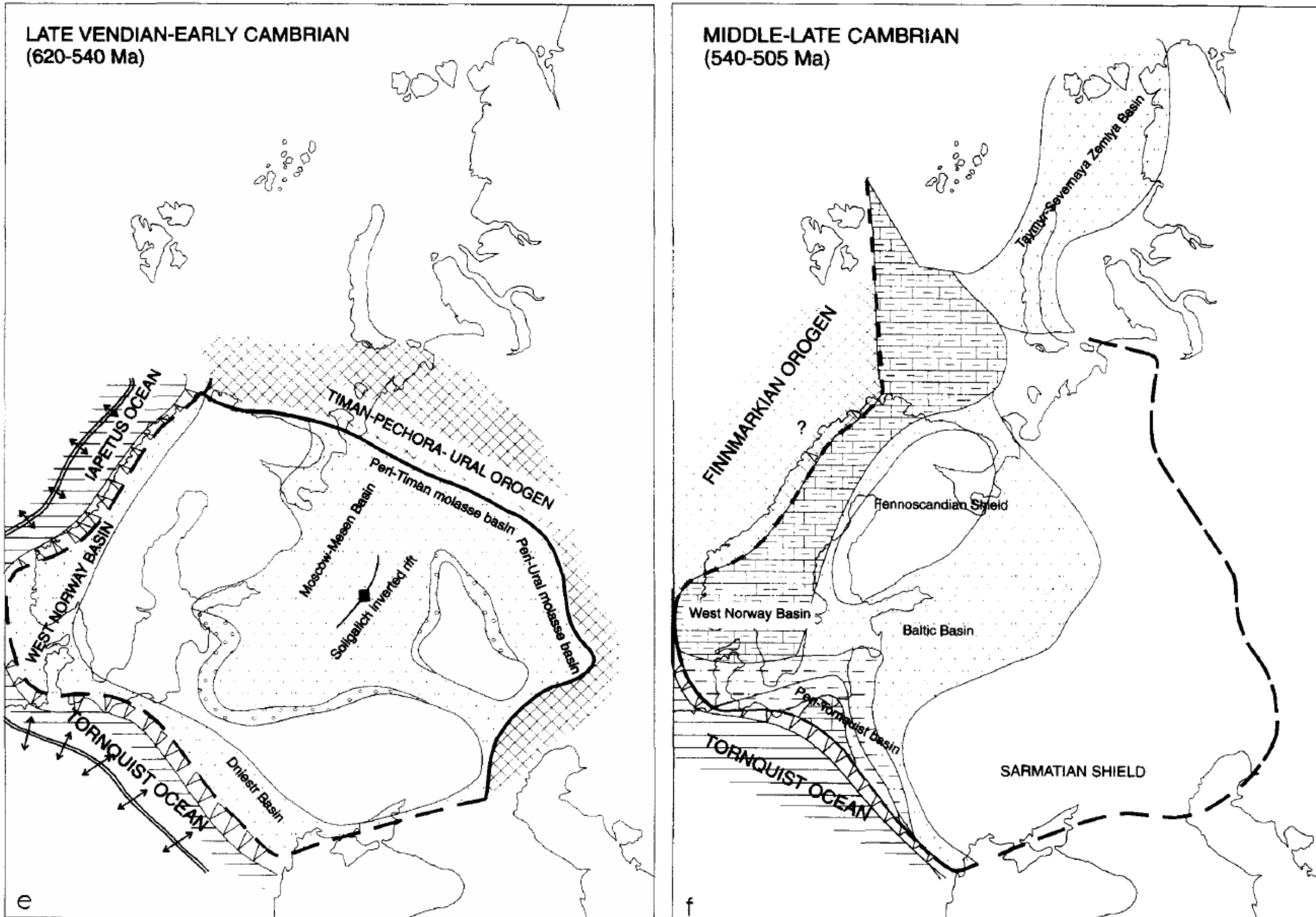
Oslo Graben

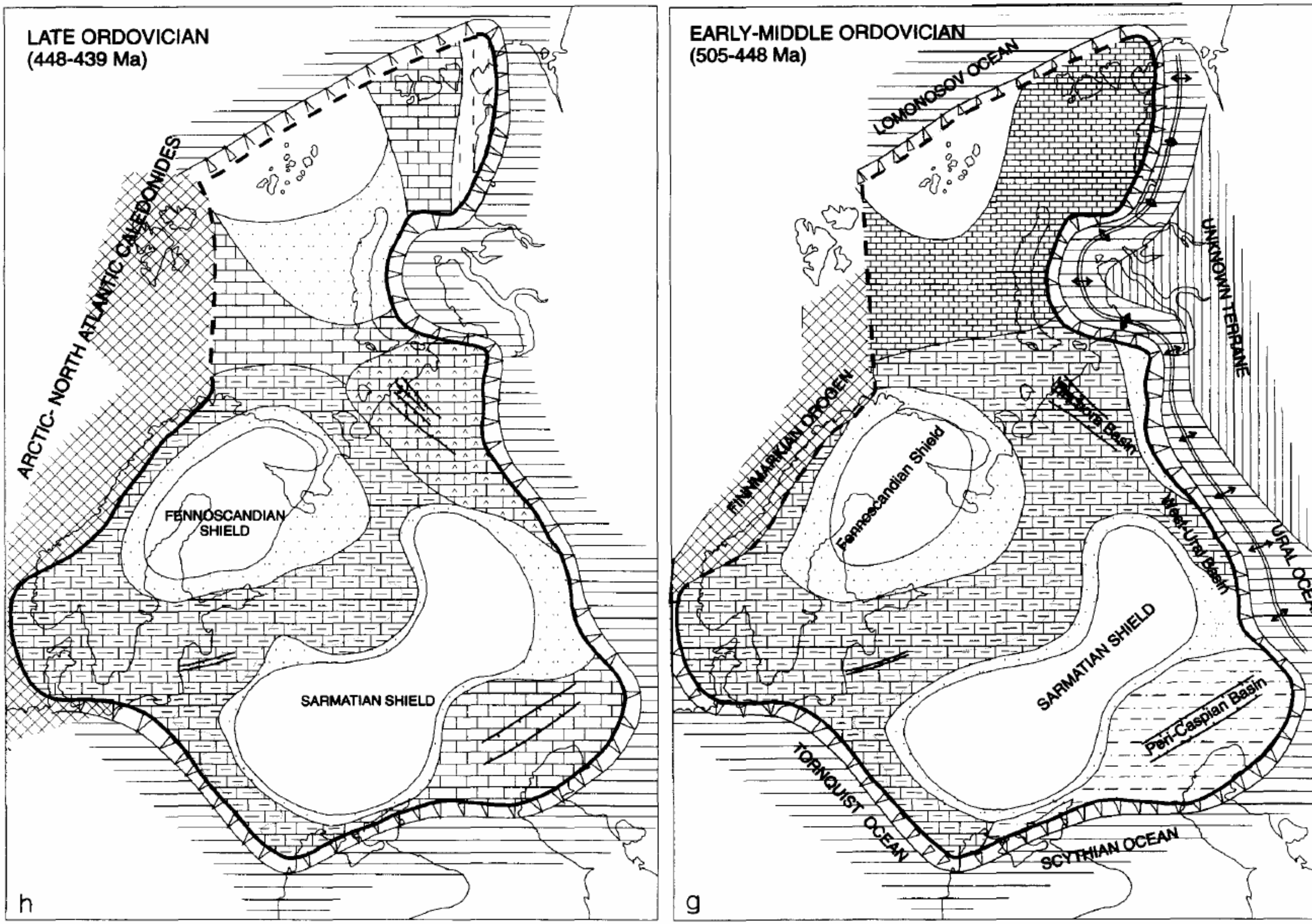
- Active between c. 320 – 240 Ma
- Preserved Cambro-Silurian (≥ 1700m)
- Upper Carboniferous Asker Group (70-80m)
- U-Carb. – Permian igneous rocks (basalts/RP & intrusives)
- Permian sediments

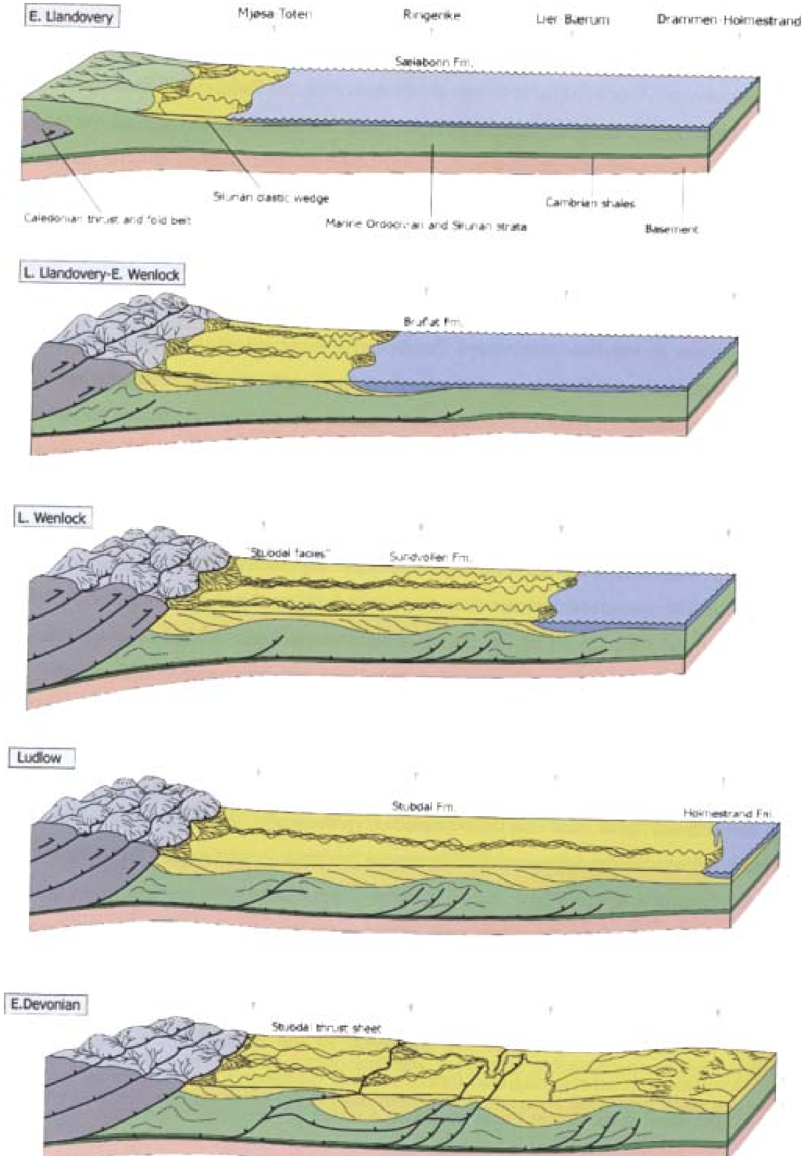
Lower Paleozoic

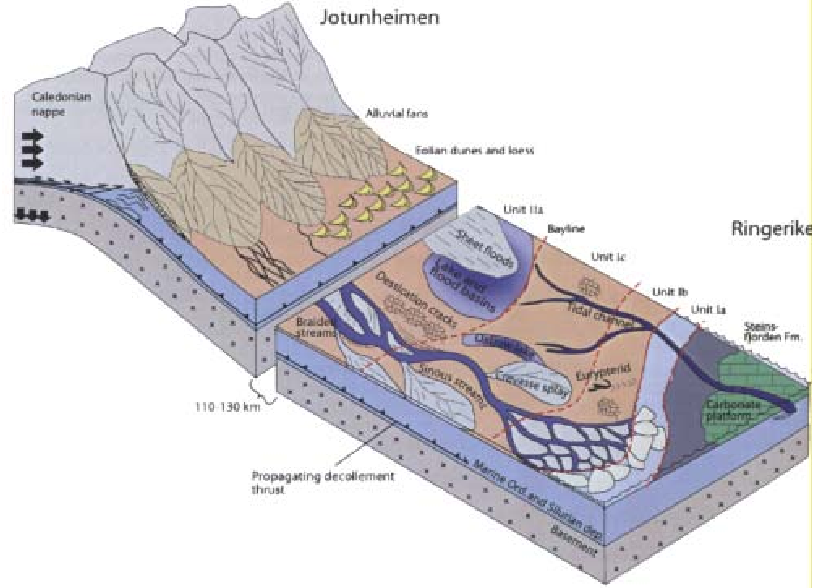


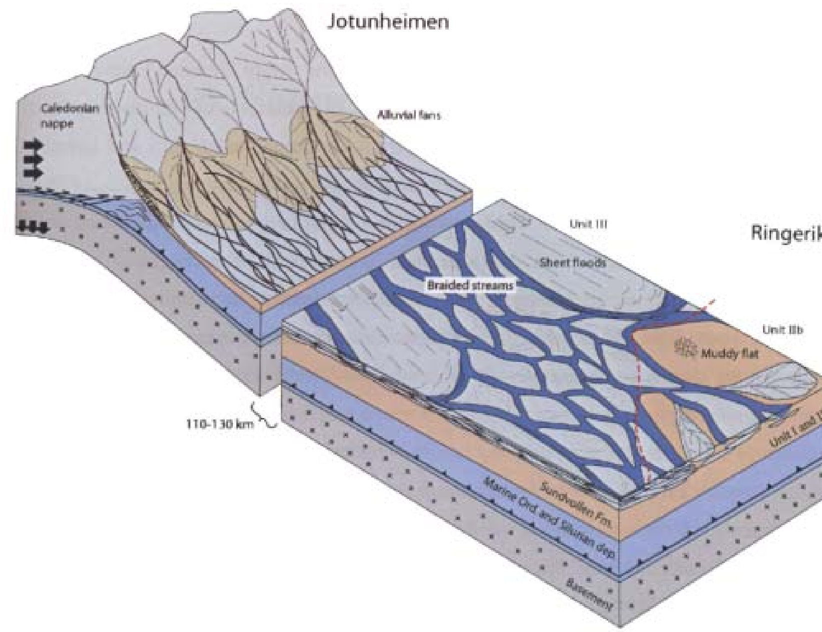
- Cambrian:
  - Marine transgression over Precambrian peneplain
- Lower-Middle Ordovician
  - Fairly stable marine conditions; changing oxygen content
- Late Ordovician
  - Erosional products; sea-level drops
- Silurian
  - Caledonian Orogeny
  - Foreland basin in-fill

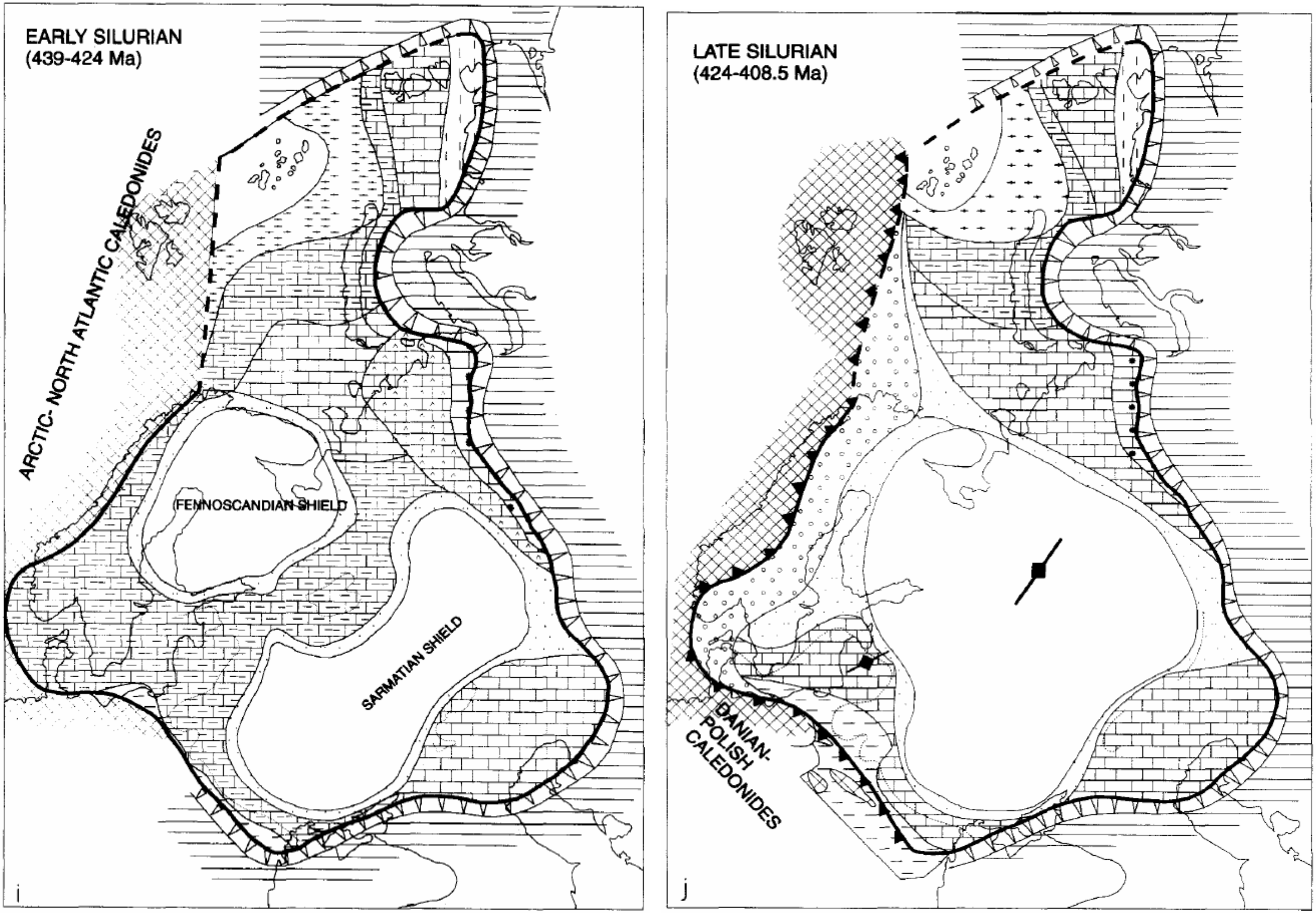

LATE VENDIAN-EARLY CAMBRIAN
(620-540 Ma)
IAPETUS OCEAN
WEST NORWAY BASIN
TIMAN-PECHORA- URAL OROGEN
Peri-Timan molasse basin
Peri-Ural molasse basin
Moscow-Mesen Basin
Soligalich inverted rift
TORNQUIST OCEAN
Dniestr Basin
e
MIDDLE-LATE CAMBRIAN
(540-505 Ma)
Taymyr-Severnaya Zemlya Basin
FINNMARKIAN OROGEN
?
Fennoscandian Shield
West Norway Basin
Baltic Basin
Peri-Tornquist basin
TORNQUIST OCEAN
SARMATIAN SHIELD
f


LATE ORDOVICIAN
(448-439 Ma)
ARCTIC- NORTH ATLANTIC CALEDONIDES
FENNOSCANDIAN SHIELD
SARMATIAN SHIELD
h
EARLY-MIDDLE ORDOVICIAN
(505-448 Ma)
LOMONOSOV OCEAN
UNKNOWN TERRANE
FINNMARKIAN OROGEN
Fennoscandian Shield
West-Ural Basin
URAL OCEAN
SARMATIAN SHIELD
Peri-Caspian Basin
TORNQUIST OCEAN
SCYTHIAN OCEAN
g


E. Llandovery
Mjøsa Toten
Ringerike
Lier Bærum
Drammen-Holmestrand
Sælabonn Fm.
Caledonian thrust and fold belt
Silurian clastic wedge
Marine Ordovician and Silurian strata
Cambrian shales
Basement
L. Llandovery-E. Wenlock
Bruflat Fm.
L. Wenlock
"Stubdal facies"
Sundvollen Fm.
Ludlow
Stubdal Fm.
Holmestrand Fm.
E.Devonian
Stubdal thrust sheet


Jotunheimen
Caledonian nappe
Alluvial fans
Eolian dunes and loess
Unit IIa
Bayline
Ringerike
Unit Ic
Sheet floods
Lake and flood basins
Desiccation cracks
Unit Ib
Unit Ia
Tidal channel
Steins-fjorden Fm.
Braided streams
Eurypterid
Crevasse splay
Sinous streams
Carbonate platform
110-130 km
Propagating decollement thrust
Marine Ord and Silurian dep.
Basement


Jotunheimen
Caledonian nappe
Alluvial fans
Unit III
Ringerike
Sheet floods
Braided streams
Unit IIb
Muddy flat
110-130 km
Unit I and IIa
Sundvollen Fm.
Marine Ord and Silurian dep.
Basement


EARLY SILURIAN
(439-424 Ma)
ARCTIC- NORTH ATLANTIC CALEDONIDES
FENNOSCANDIAN SHIELD
SARMATIAN SHIELD
i
LATE SILURIAN
(424-408.5 Ma)
DANIAN-
POLISH
CALEDONIDES
j

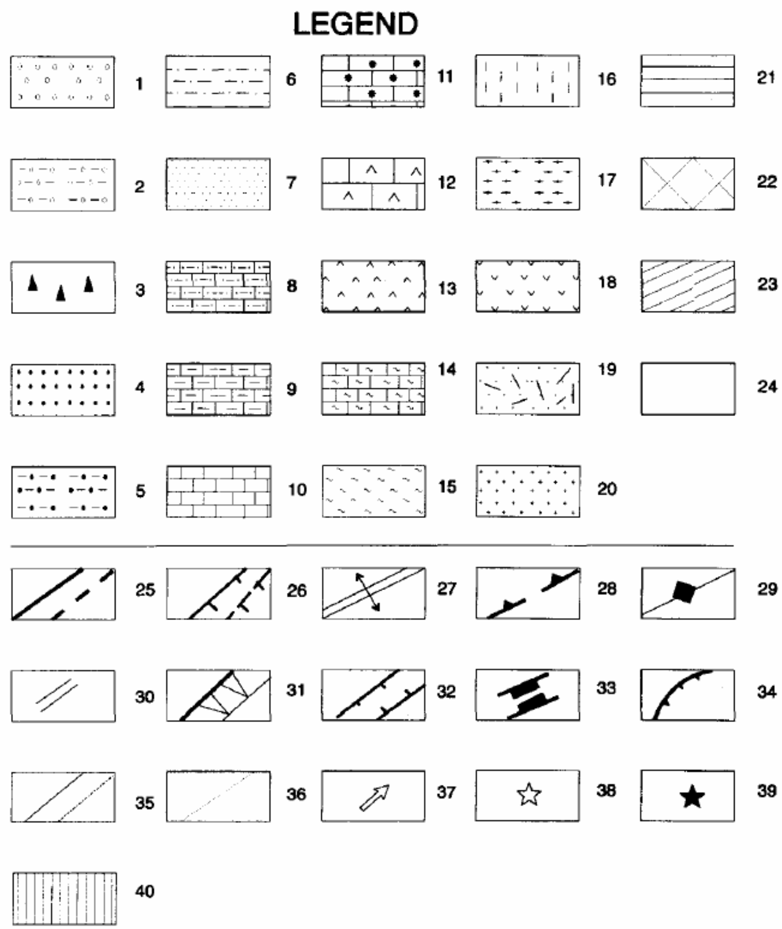
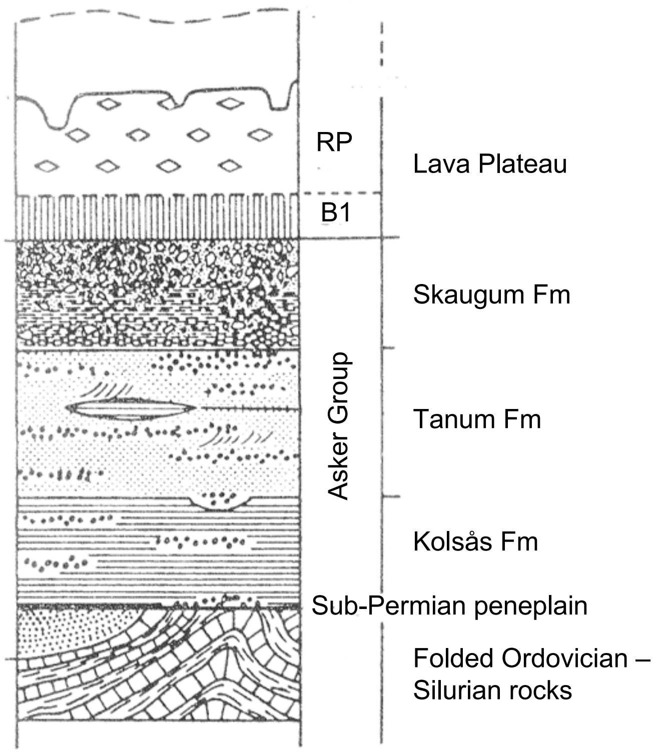


Fig. 7. Palaeotectonic/palaeogeographic maps of the East European Craton. Legend: *1* = continental sands; *2* = continental sands and shales; *3* = tillites (Early Vendian); *4* = alluvial-deltaic and shallow-marine, mainly sands; *5* = alluvial-deltaic and shallow-marine sands and shales; *6* = shallow-marine sands and shales; *7* = alluvial-deltaic and shallow-marine sands and shales (for Precambrian and earliest Cambrian only); *8* = shallow-marine sands, shales and carbonates; *9* = shallow-marine carbonates and shales; *10* = mainly carbonates; *11* = carbonates, mainly coral and/or algal; *12* = carbonates and evaporites; *13* = mainly evaporites; *14* = deeper-marine carbonates, clays and siliceous shales; *15* = deeper-marine clays and siliceous shales; *16* = deeper-marine clastics and/or carbonates; *17* = turbiditic series, flysch; *18* = plateau basalts; *19* = acid volcanites and clastics; *20* = granite intrusions (for Early Riphean); *21* = oceanic basin; *22* = active fold belts; *23* = inactive fold belts; *24* = cratonic highs; *25* = boundaries of the craton and main tectonic units; *26* = major active faults; *27* = spreading axes; *28* = subduction zones; *29* = inversion axes; *30* = dyke systems (Precambrian); *31* = continental slope; *32* = rifts; *33* = highly stretched continental or oceanic crust; *34* = active major thrusts; *35* = boundaries of lithological zones; *36* = erosional edge of mapping interval; *37* = directions of clastic influx; *38* = orogenic volcanism; *39* = basaltic volcanism; *40* = unknown continental terrane.

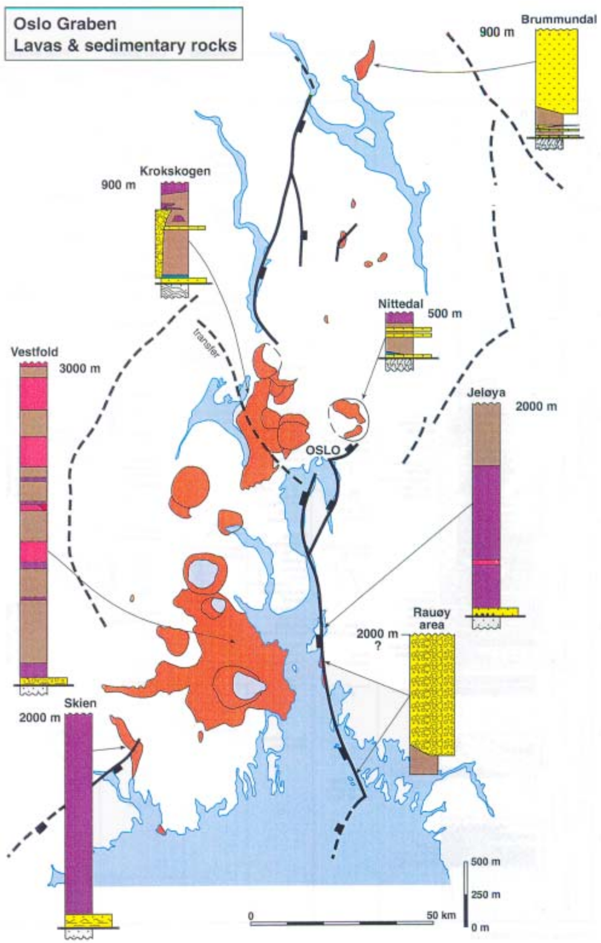
Upper Paleozoic sediments

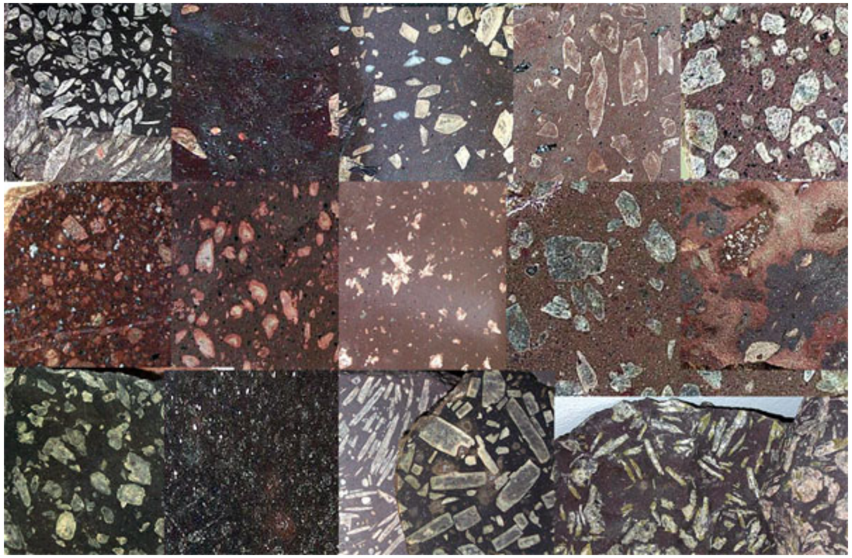
Krokskogen, Tyrifjorden



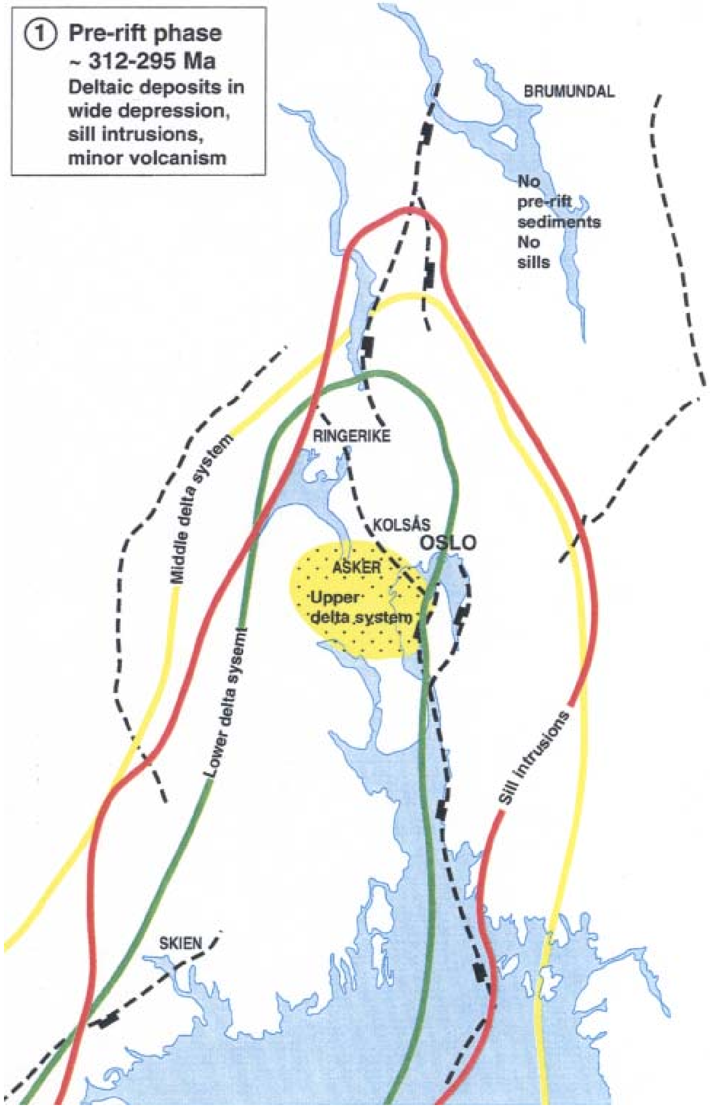
- Asker Group
  - Deposited on a eroded peneplain (20° North)
  - Continental deposits (rivers, deltas)
- Kolsås Fm
  - Red shales; some sst and lst; 15m
- Tanum Fm
  - Sst and Cgl; lst as cement; 15m
  - 1m thick marine lst
- Skaugum Fm
  - Red shales and sst; volcanic detritus; 20m

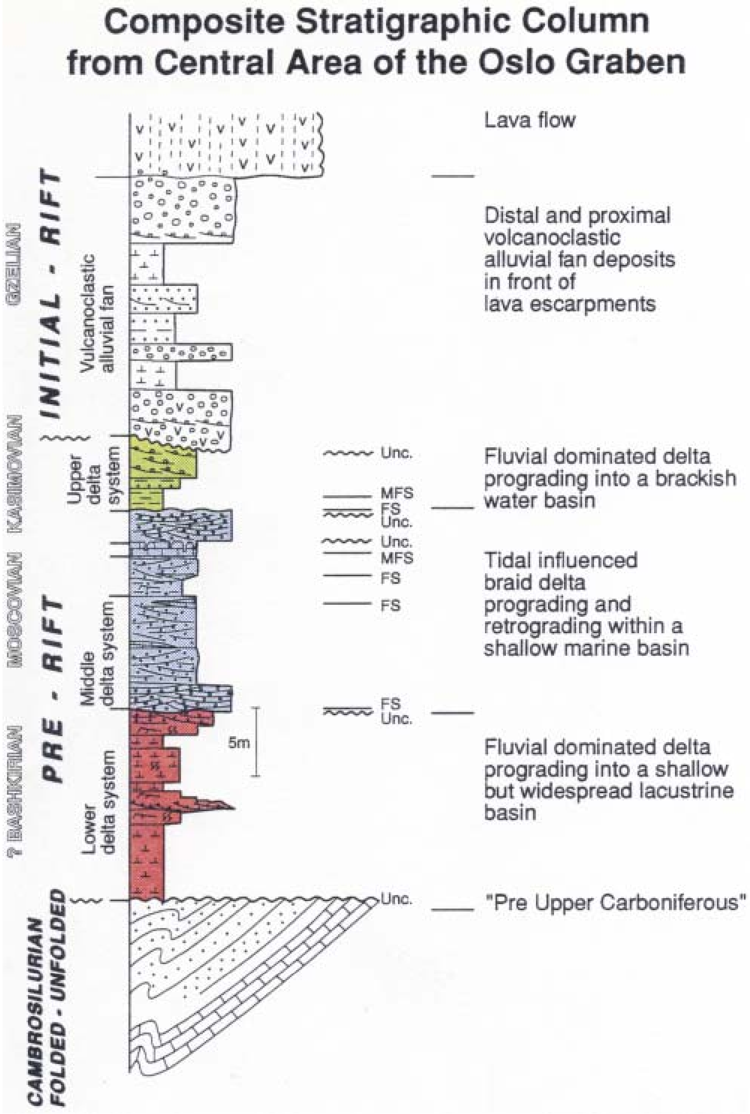
Upper-Carboniferous – Permian lavas and sedimentary rocks



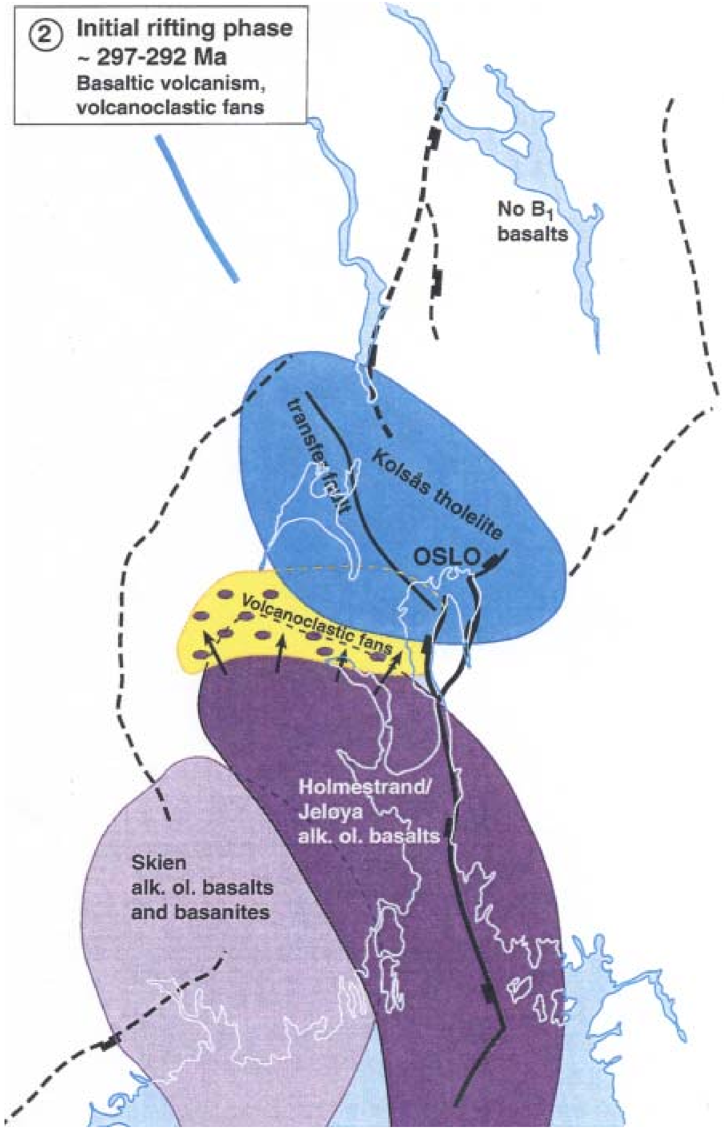


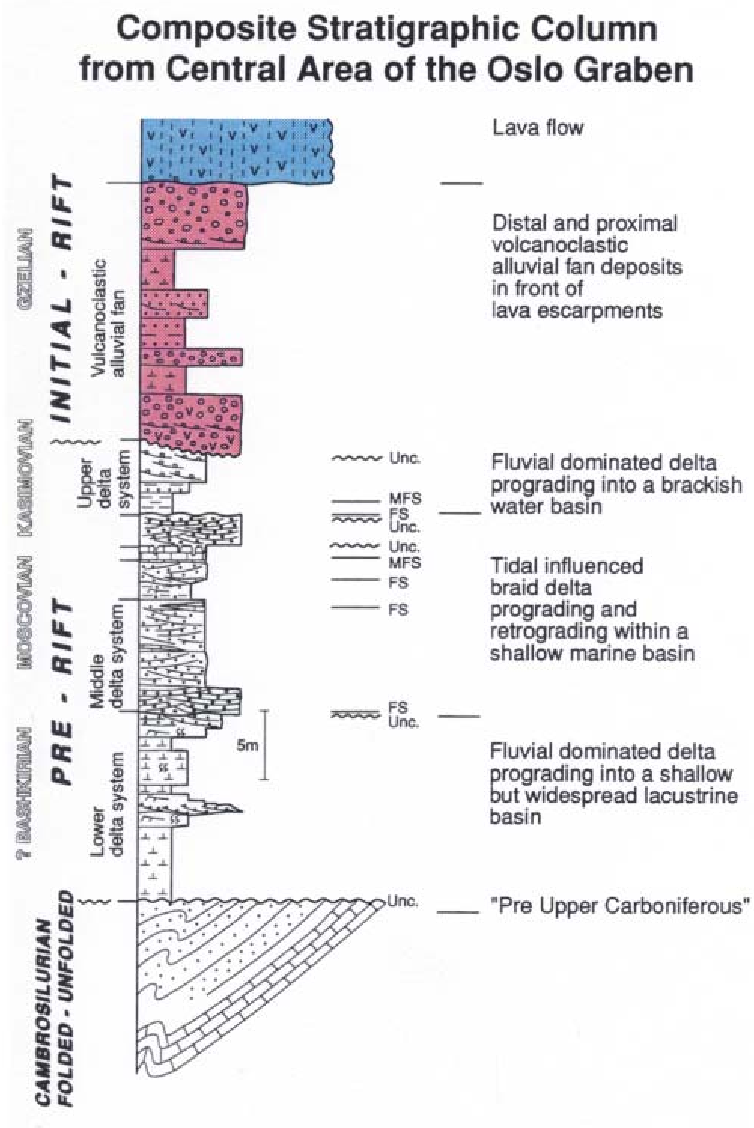
Graben Formation



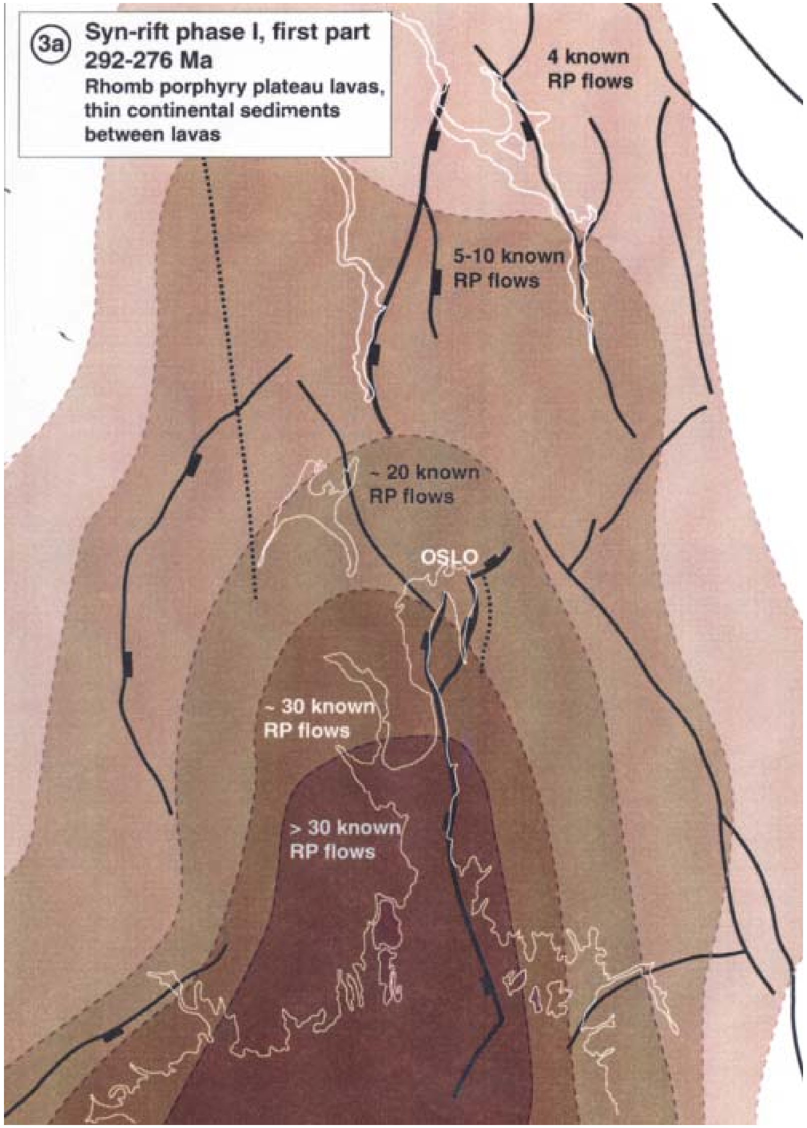


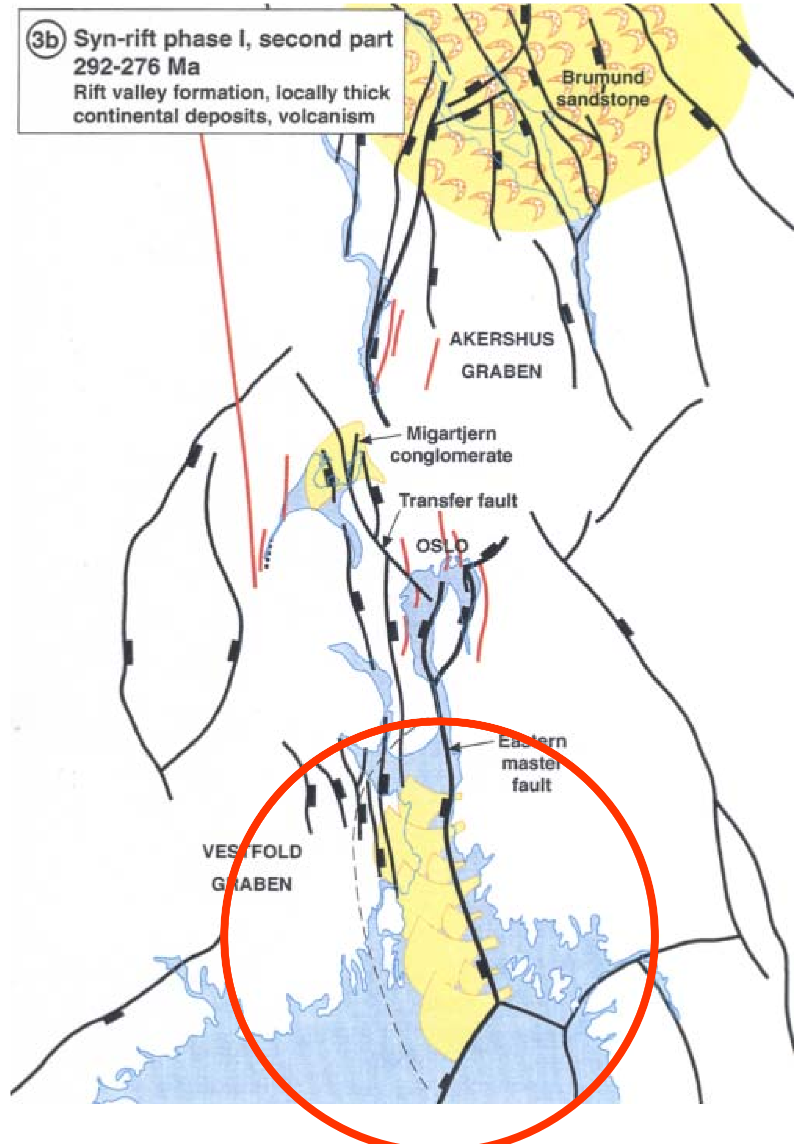
Graben Formation

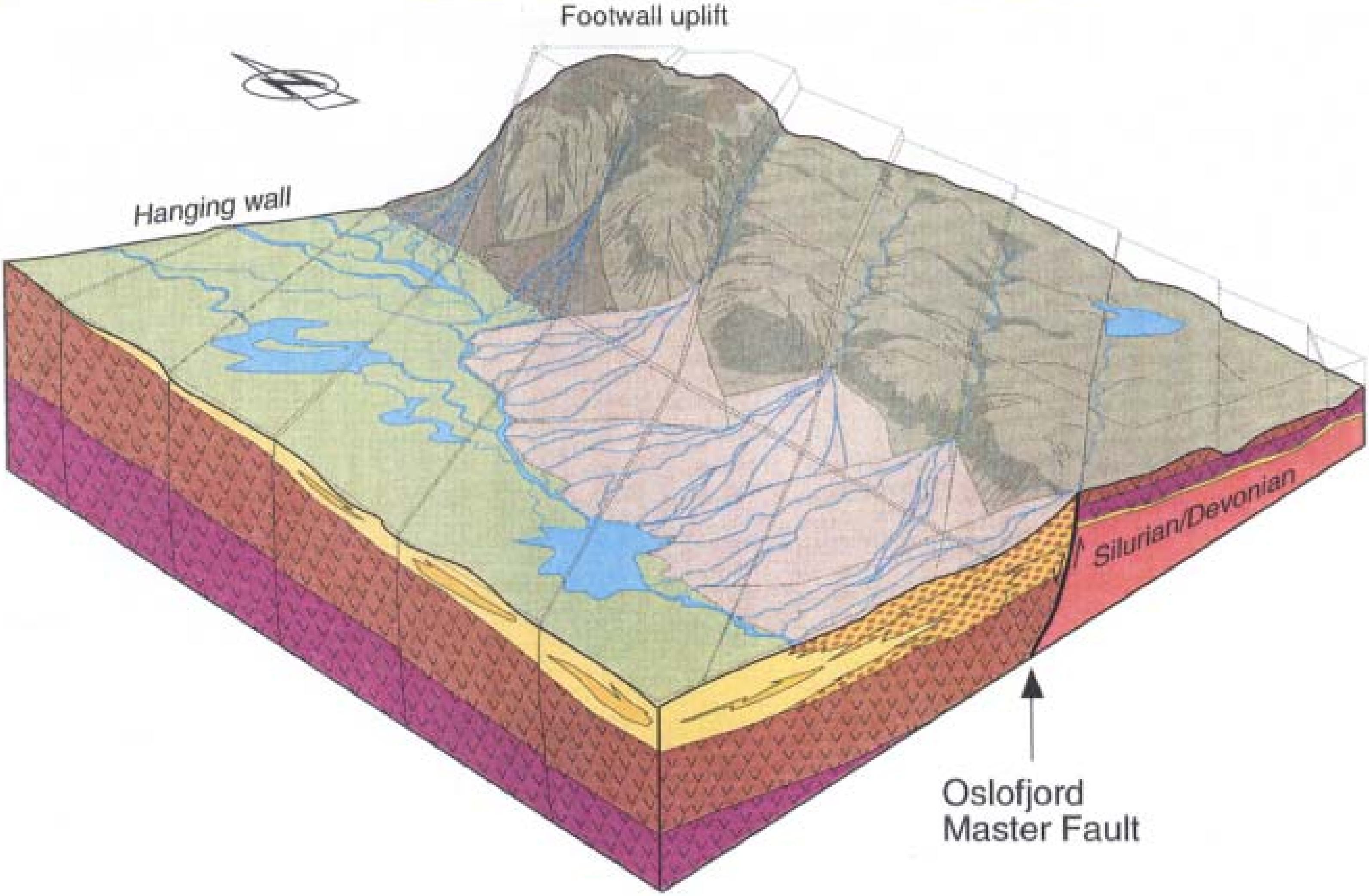




Graben Formation

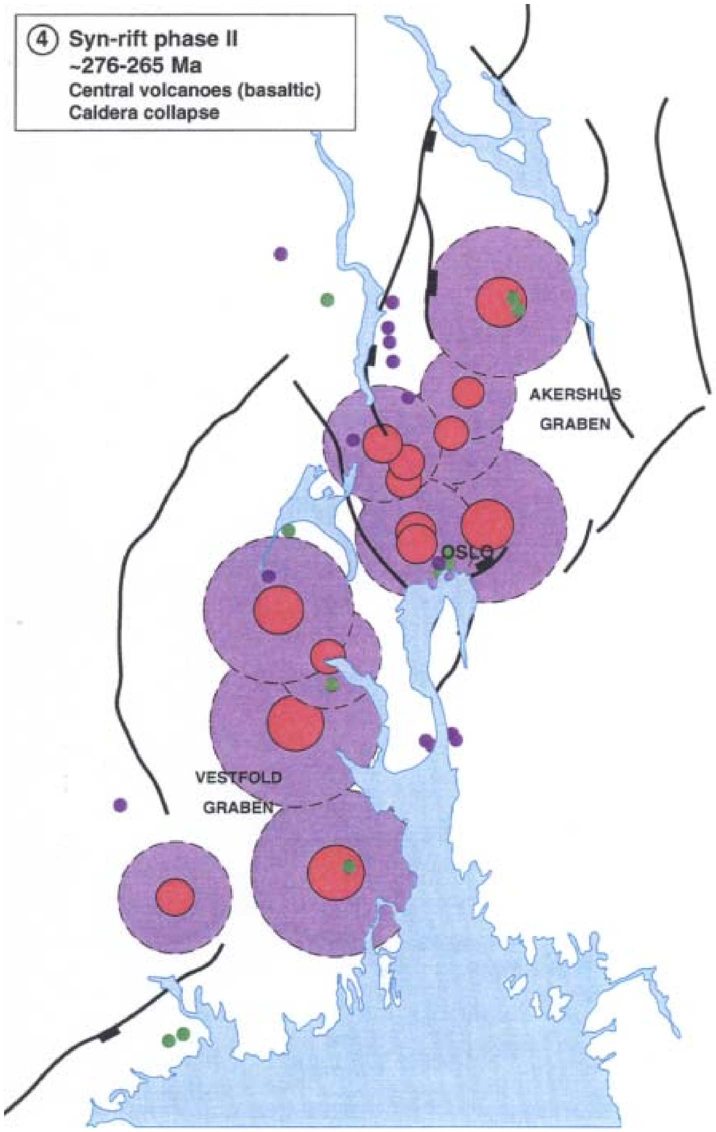


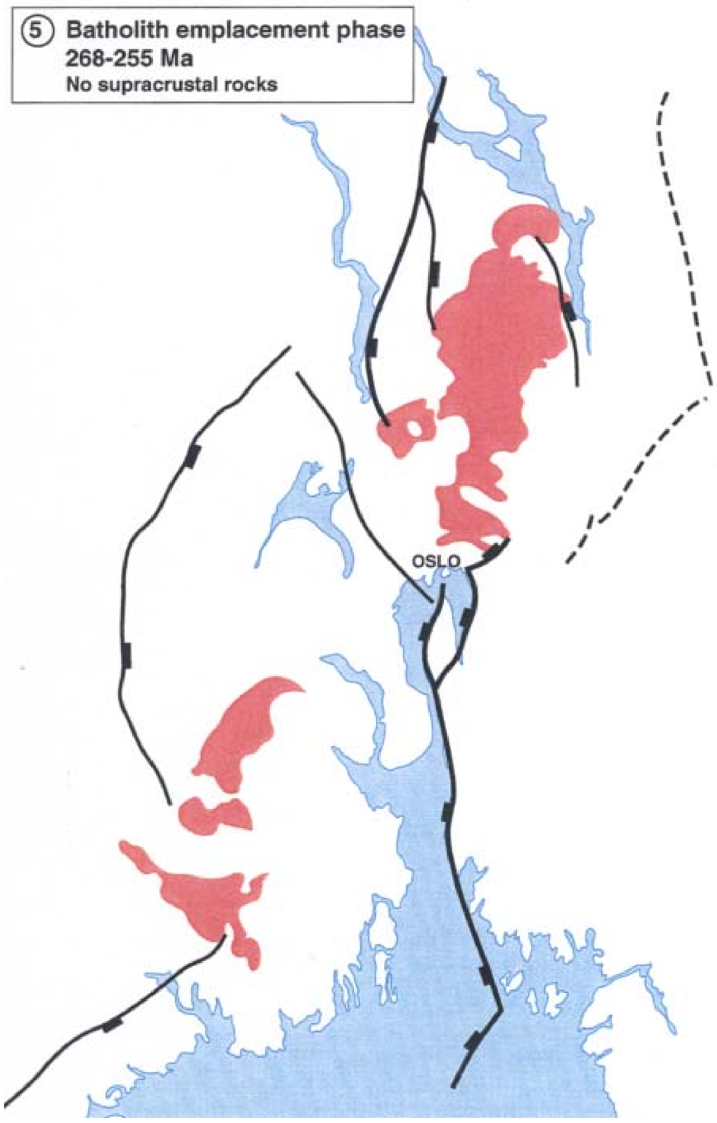


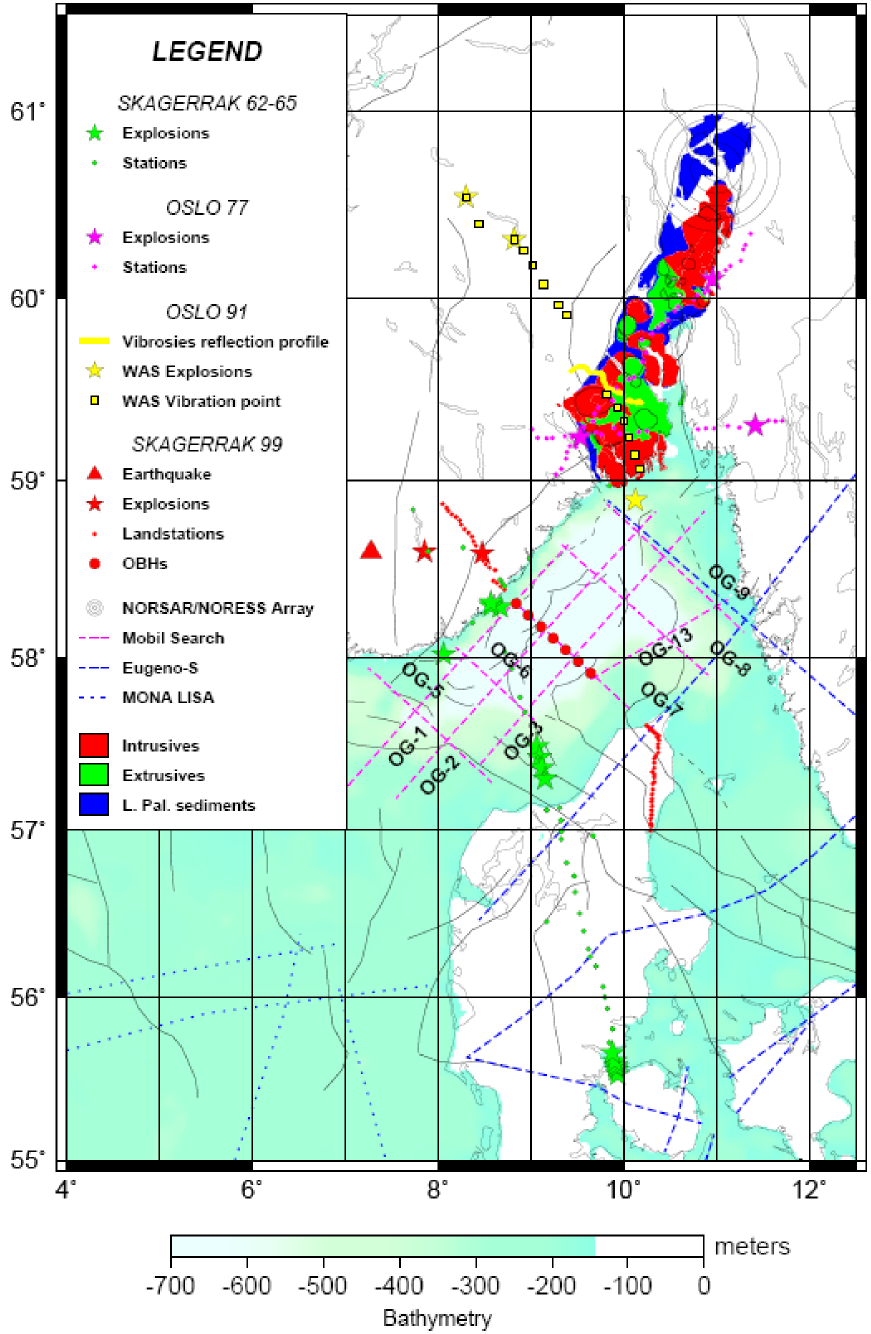


Thick volcaniclastic alluvial fans banked against the master fault

Graben Formation



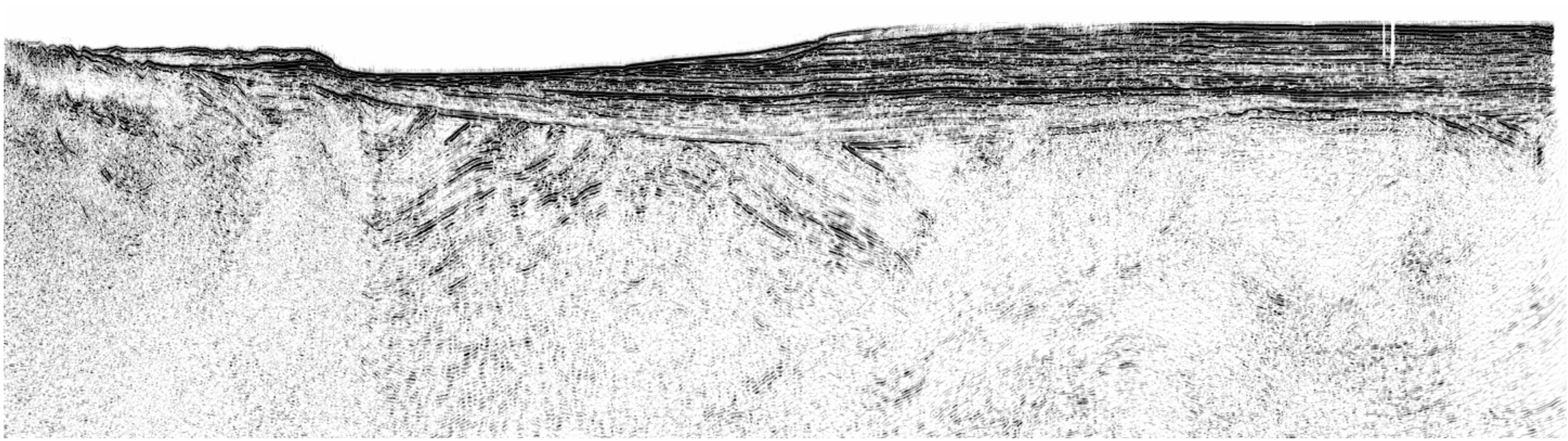




Correlation between Oslo Graben and Skagerrak Graben

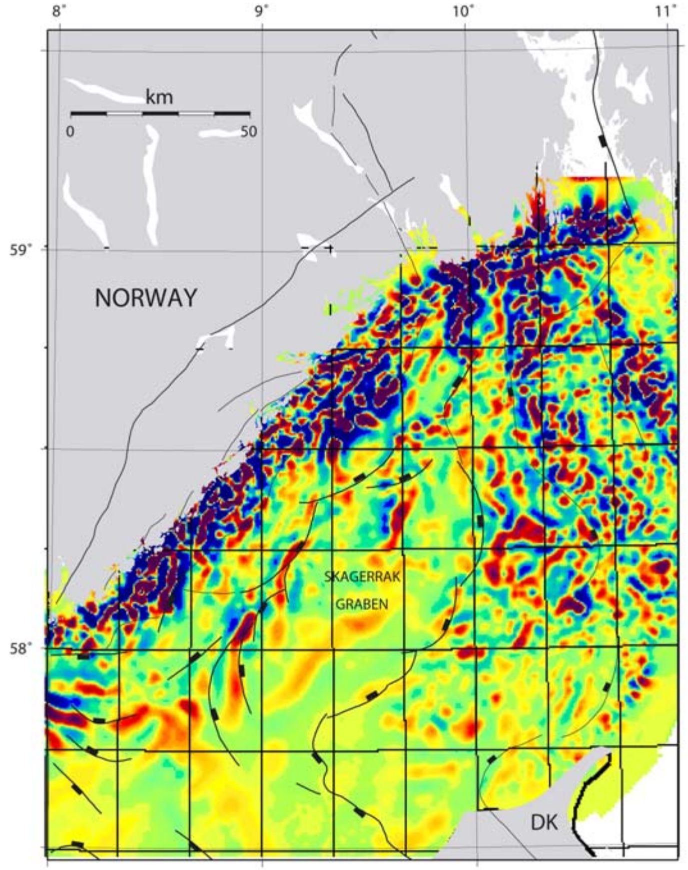
- Oslo Graben:
  - Surface geology
  - Stratigraphy
  - No information on depth
- Skagerrak Graben
  - Below sea-level
  - Seismic sections
  - Depth information
  - No control on geology

Seismic line OG-7



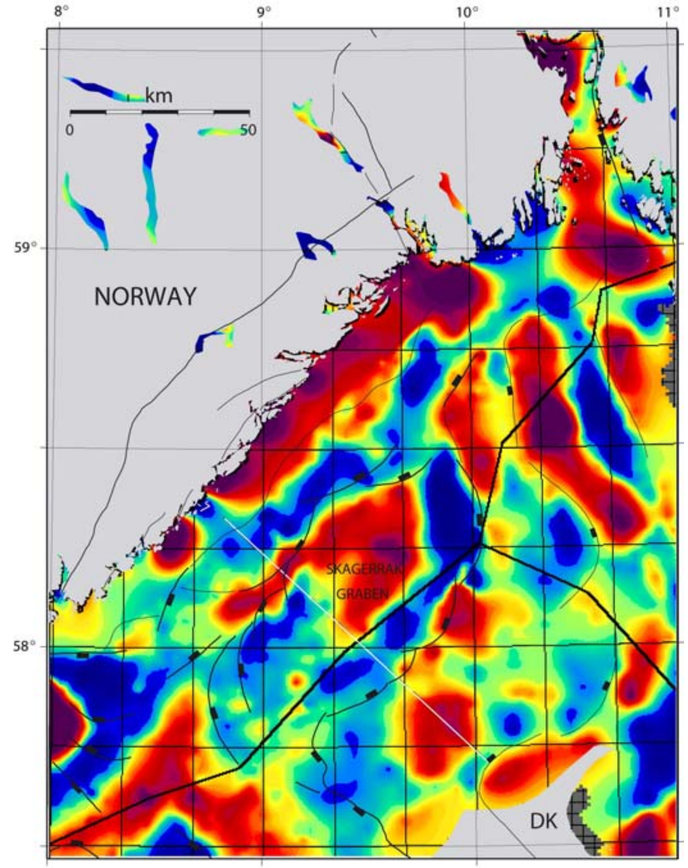
Potential Field Data

OSLO RIFT IN SKAGERRAK



MAIN STRUCTURAL ELEMENTS + MAGNETIC RESIDUALS HIGH PASS FILTERED 8 KM

OSLO RIFT IN SKAGERRAK

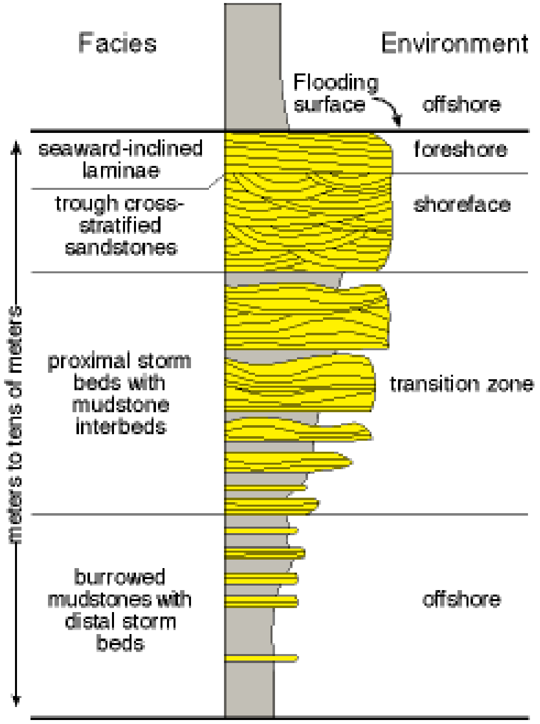


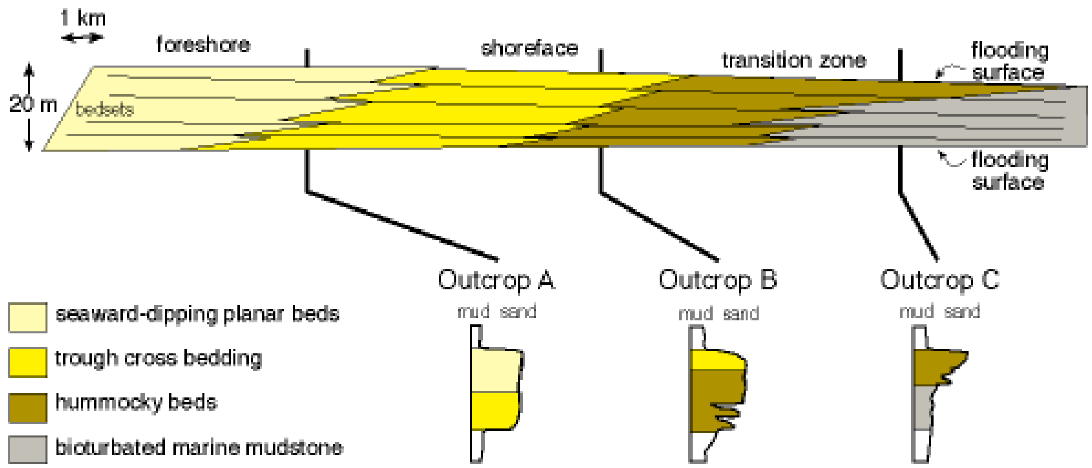
MAIN STRUCTURAL ELEMENTS + BOUGUER RESIDUALS HIGH PASS FILTERED 50 KM

How to correlate OG and SG

- Logging stratigrafic section
- Divide section into seismic sequences
- Define acoustic impedance of seismic sequences
- Calculate reflection coefficient
- Construct synthetic seismogram
- Correlate with seismic

Stratigraphic logging





SCALE?

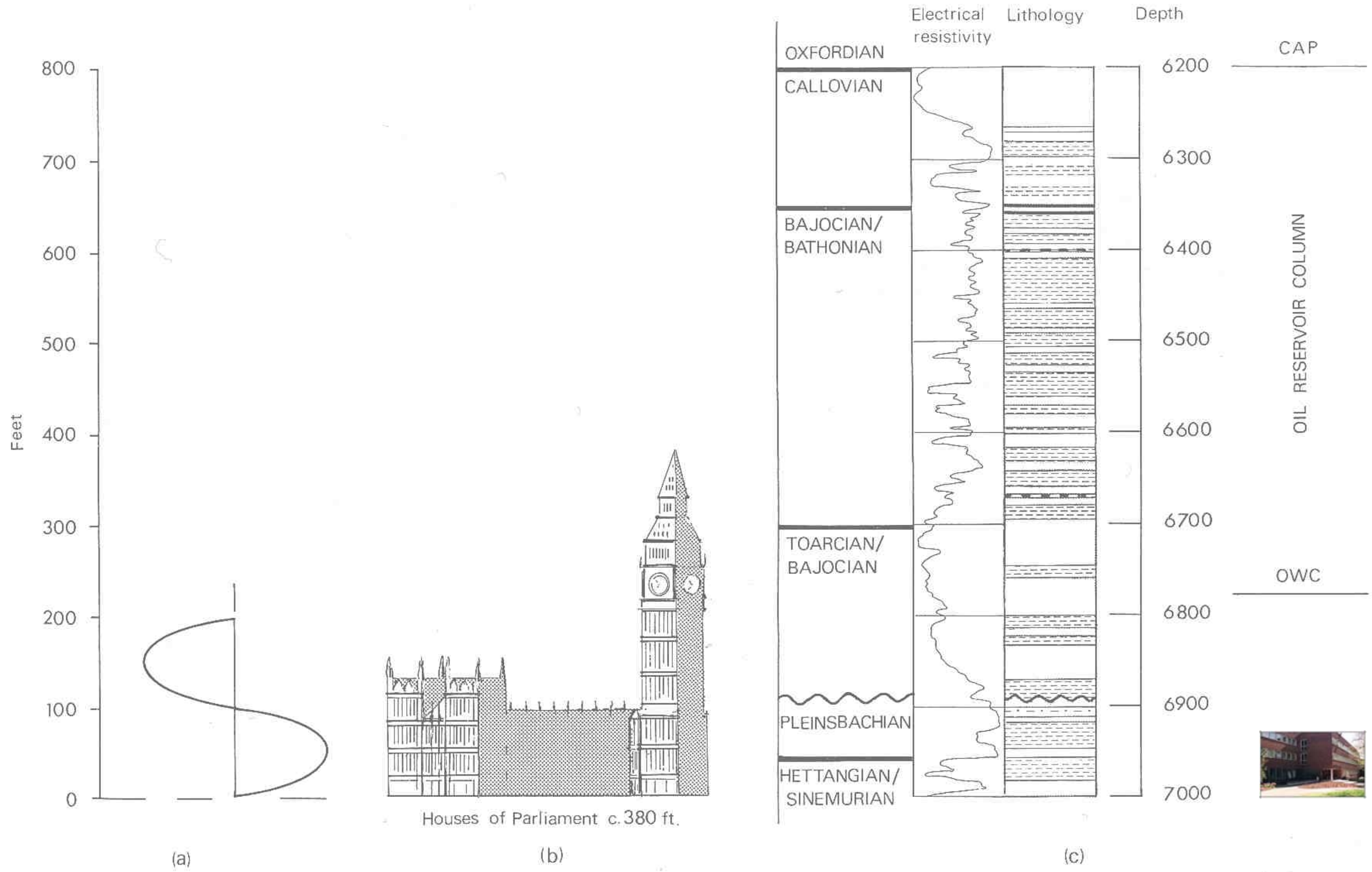
Seismic scale

Table 1-1. Typical Limits of Visibility and Separability for a range of geologic situations.

Age of rocks				VERY YOUNG	YOUNG	MEDIUM	OLD	VERY OLD
Depth of target				VERY SHALLOW	SHALLOW	MEDIUM	DEEP	VERY DEEP
Formation Velocity (m/s)				1600	2000	3500	5000	6000
Predominant Frequency (Hz)				70	50	35	25	20
Wavelength (m)			λ	23	40	100	200	300
LIMIT OF SEPARABILITY			$\frac{\lambda}{4}$	**6**	**10**	**25**	**50**	**75**
LIMIT OF VISIBILITY								
Poor S/N	e.g.	Water sand poor data	$\sim\frac{\lambda}{8}$	**3**	**5**	**13**	**25**	**38**
Moderate S/N	e.g.	Water or oil sand fairly good data	$\sim\frac{\lambda}{12}$	**2**	**3**	**8**	**17**	**25**
High S/N	e.g.	Gas sand good data	$\sim\frac{\lambda}{20}$	**1**	**2**	**5**	**10**	**15**
Outstanding S/N	e.g.	Gas sand excellent data	$\sim\frac{\lambda}{30}$	**<1**	**1**	**3**	**7**	**10**

units are meters

Seismic scale



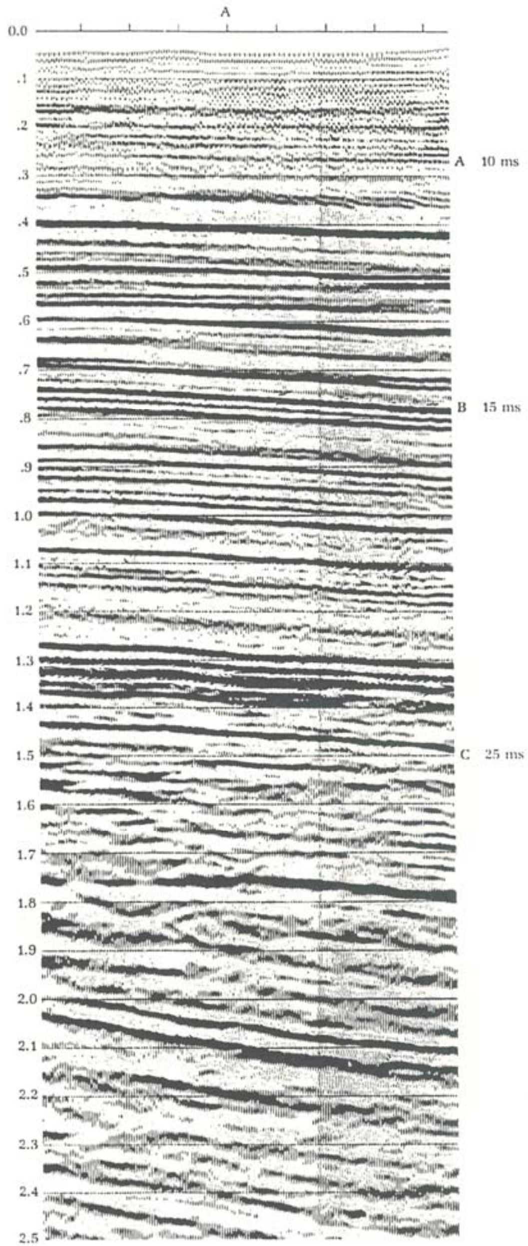
Vertical resolution

Wavelength increases
Frequency decreases
} with depth

↓

Reduced vertical resolution

f	v	λ	λ/4	z
100 Hz	2 km/s	20 m	5 m	~250 m
40 Hz	4 km/s	100 m	25 m	~2250 m

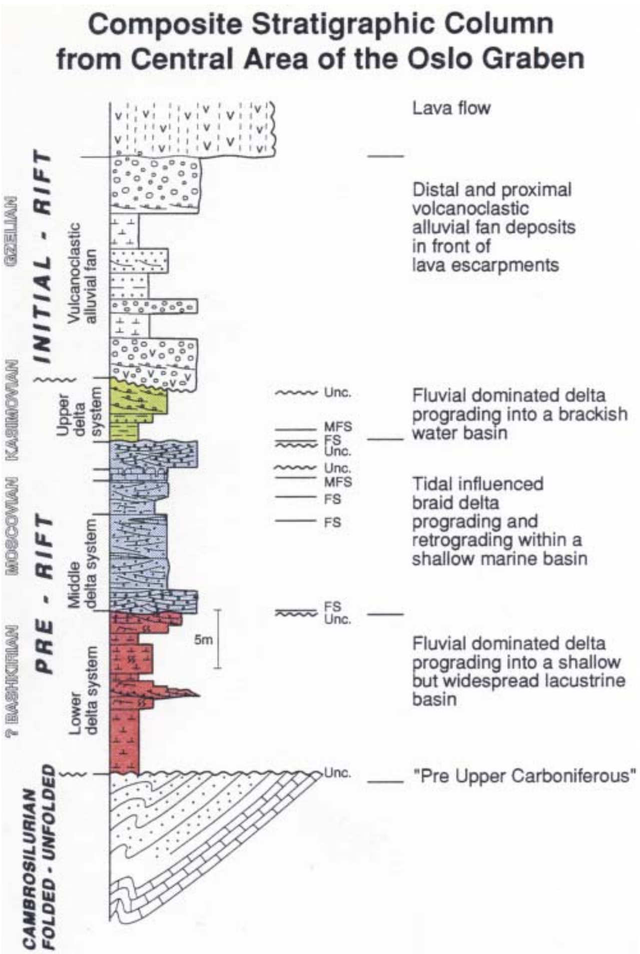


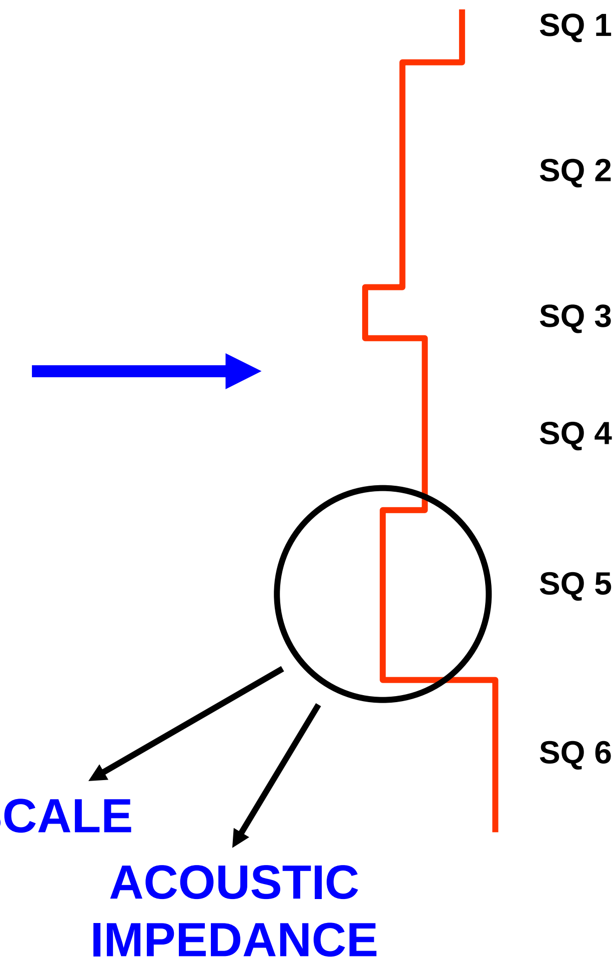
100 Hz

67 Hz

40 Hz

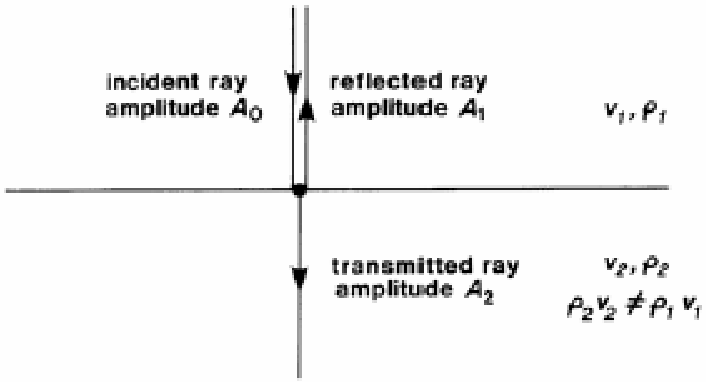
Seismic sequences

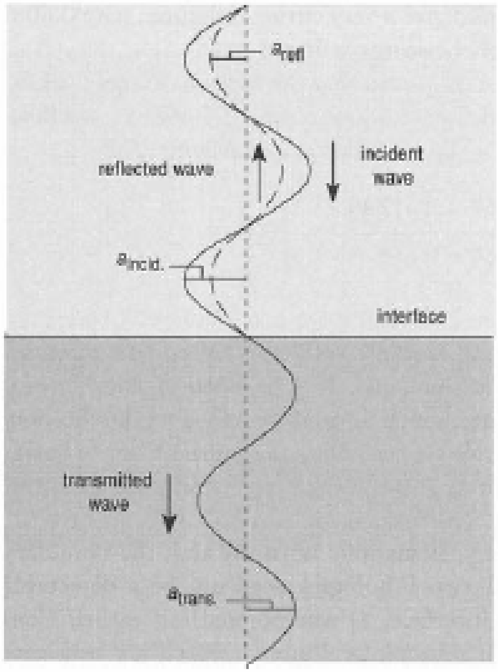




WHAT IS A REFLECTOR: HOW CAN IT BE DEFINED (how strong it is)?

Normally Incident Seismic Rays





acoustic impedance $Z = \rho v$

reflection coefficient $R = A_1 / A_0 = A_{refl} / A_{incid}$

$$R = \frac{\rho_2 v_2 - \rho_1 v_1}{\rho_2 v_2 + \rho_1 v_1} = (Z_2 - Z_1) / (Z_2 + Z_1)$$

$-1 \leq R \geq +1$

R = 0 → *all incident energy transmitted ($Z_1 = Z_2$)*

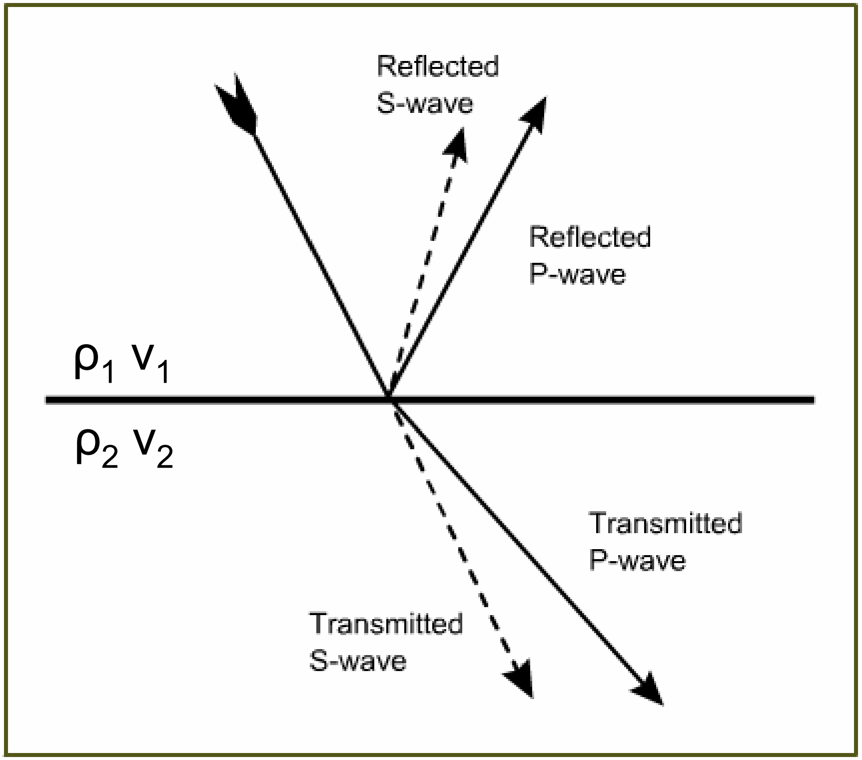
R = +1 or -1 → *all incident energy reflected*

R < 0 → *phase change π (180°) in reflected ray*

transmission coefficient $T = A_2 / A_0 = A_{trans} / A_{incid}$

$$T = \frac{2\rho_1 v_1}{\rho_2 v_2 + \rho_1 v_1}$$

The energy in a seismic wave encountering an interface with different acoustic impedance above and beneath, is divided in an up going - and a down going wavefield.



$T = A_t/A_i$ $\quad T_{P1,2} = A_{Pt}/A_{Pi}$

$R = A_r/A_i$ $\quad R_{P1,2} = A_{Pr}/A_{Pi}$

Ai: amplitude of incoming wave.
At: amplitude of transmitted wave.
Ar: amplitude of reflected wave.

Expressions are for vertically incoming pressure waves.

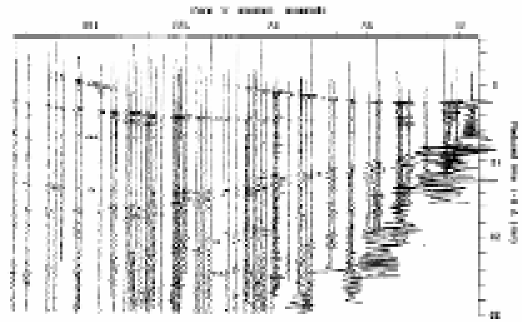
Acoustic impedance: ρ v

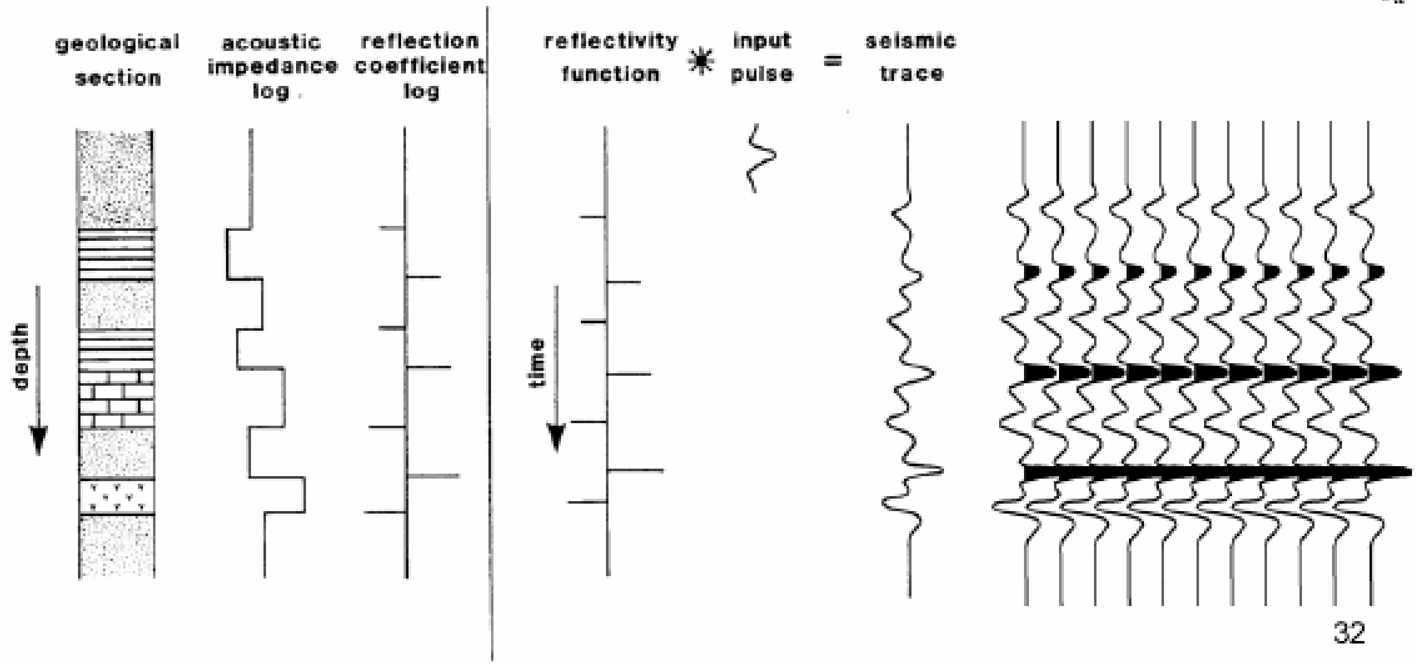
Acoustic impedance is the product between the wave velocity and the density of the medium. I=pv

The reflection and transmission coefficients express the amplitude of the waves.

SEISMIC TRACE (REFLECTION SEISMOGRAM)

***Seismic trace**:*
amplified oscillographic recording of each detector (geo-/ hydro-phone)

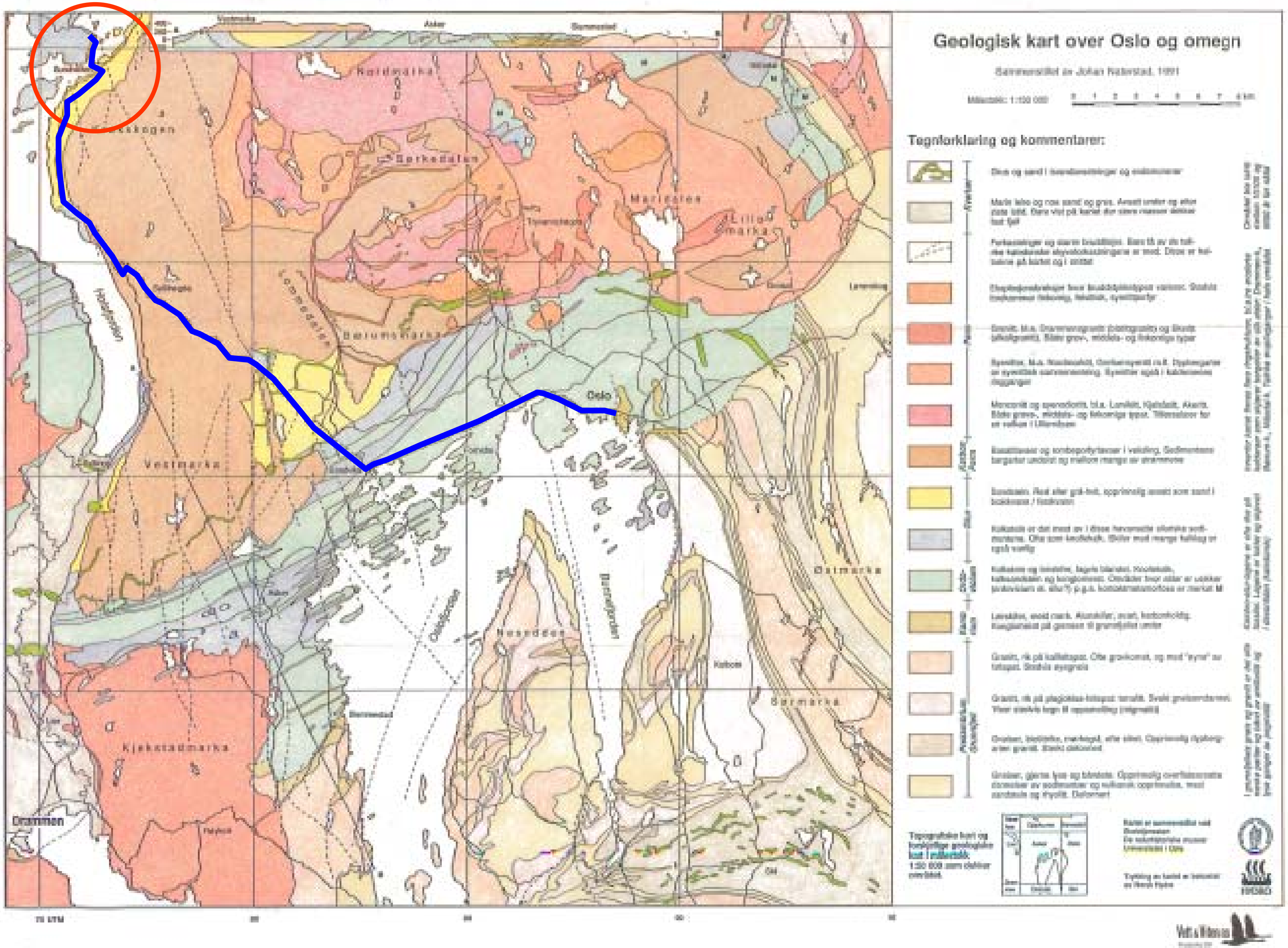


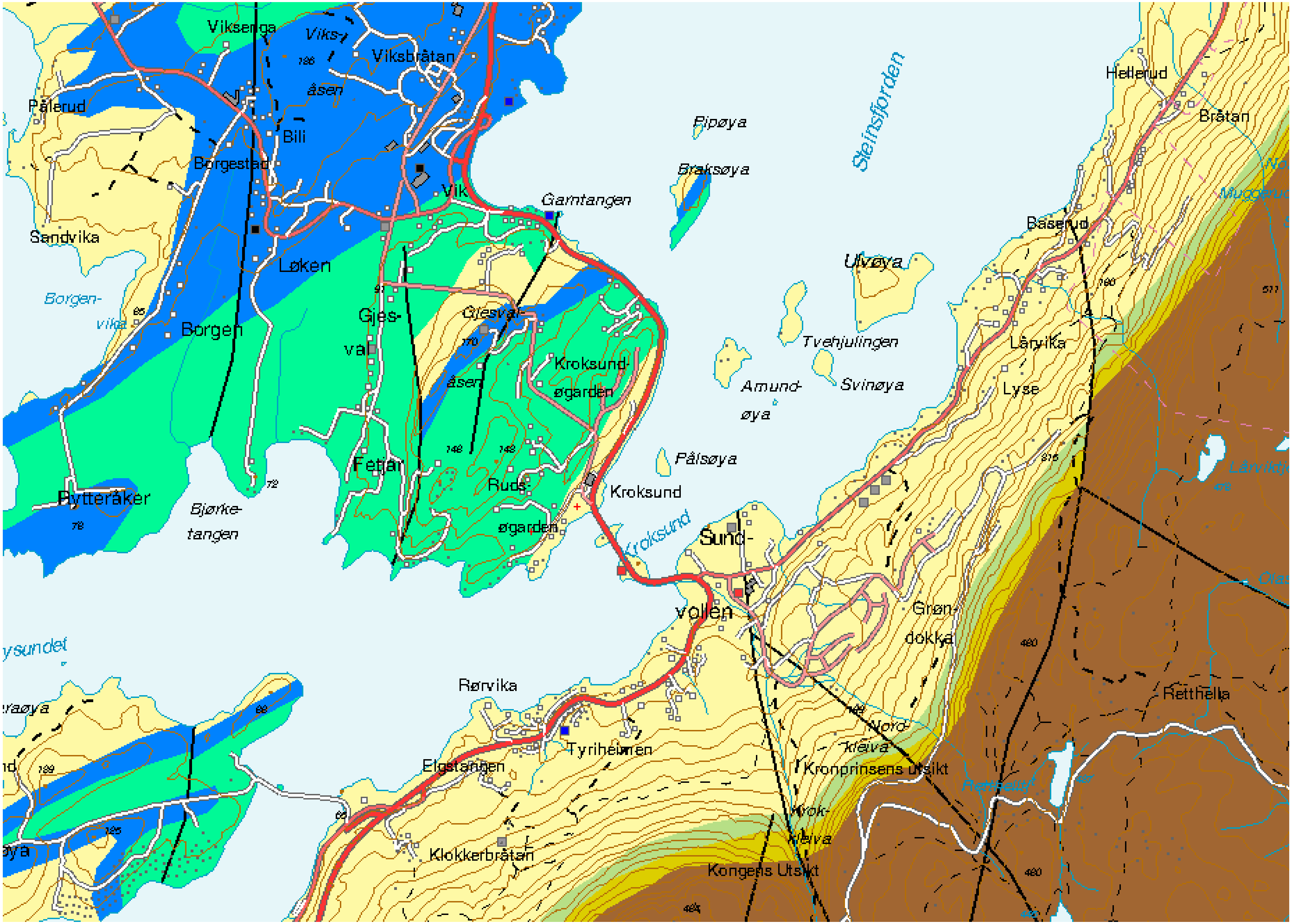


Rock Type	**Density g/cm^3**	**Vp km/s**	**Vs km/s**
water	1.0	1.5	0.0
sea water	1.03	" "	" "
oil	0.90		
coal	1.2-1.5		
sand,clay,soil (dry uncon)	1.4-2.0	2-4	1.5-3
marine seds. (unc.))	1.2-2.2	~2.5	less than 1.5
Sandstones	2.0-2.5 (up to 2.7)	2-5	
salt(rock salt)	2.1-2.45		
limestone,chalk	2.3-2.8	3-6	
Gneiss	~2.7		
Basalt	2.5-3.1		
-extruded basalt	2.5, pillows 2.8+, compacted	3.5-6.0, layer II 6.0-6.7, layer III	2-4, layer II ~4, layer III
-basalt rubble	2.1-2.4		
Granite	2.5-2.7		
Gabbro	2.8-3.1		
Diabase	2.5-3.2 2.8+, typical		
Top of mantle	3.2-3.4	~8.2 under Moho	
Lithospheric mantle		7-11	3.5-4.6

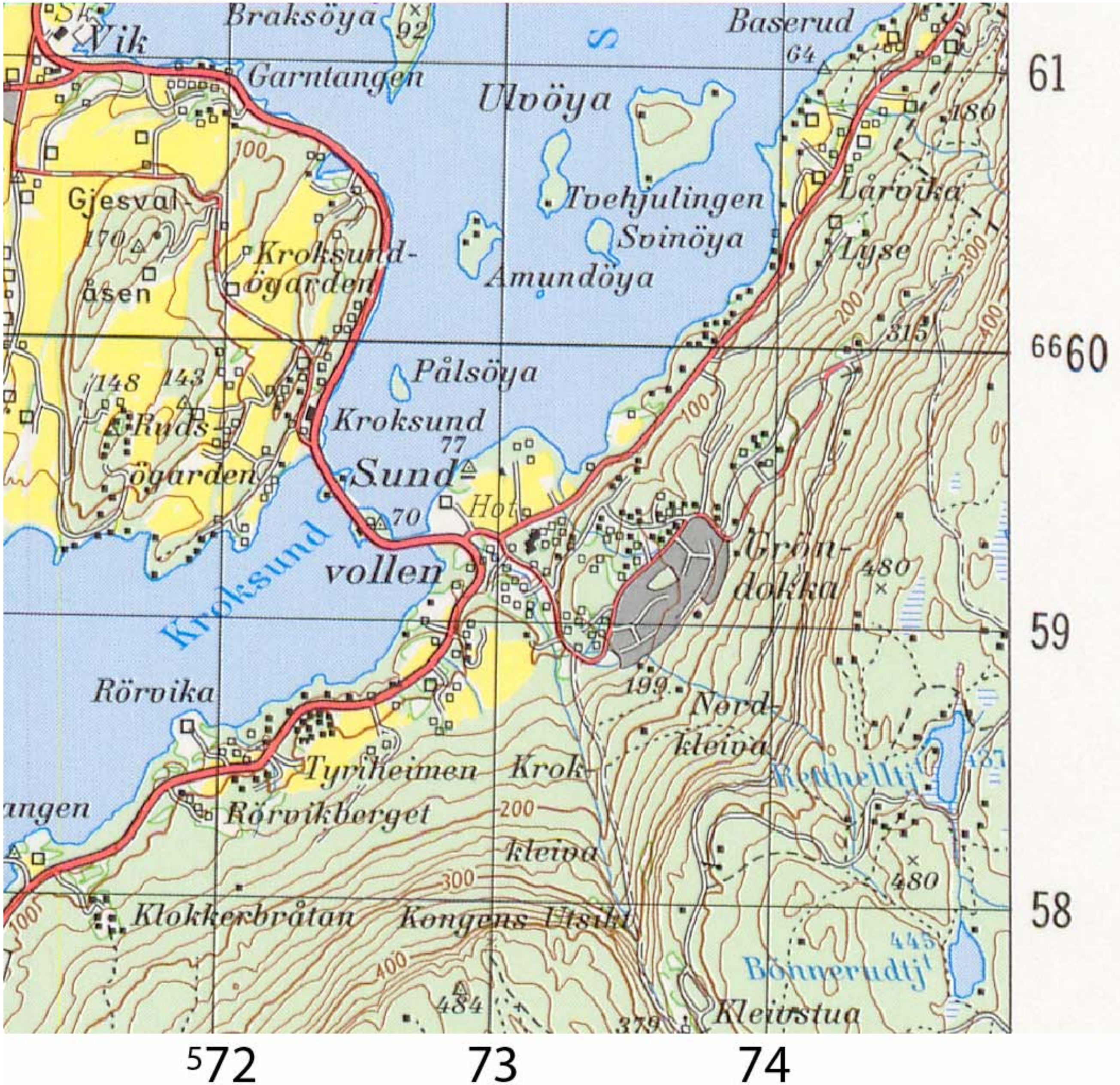
Field Trip

- Departure: 8.30 from the institute
- Arrival: c. 16.00 at the institute
- What to bring with you:
  - Lunch
  - Field book
  - Pencil and color pencils (do not use pens)
  - Clothing relative to weather
  - Light footwear (mainly roads and dirt roads)
- Other equipment is provided by us


Geologisk kart over Oslo og omegn
Tegnforklaring og kommentarer:
Nordmarka
Sørkedalen
Maridalen
Lillomarka
Bærumsmarka
Lommedalen
Vestmarka
Oslo
Østmarka
Nesodden
Sørmarka
Kjekstadmarka
Drammen



Scale: 1:25000



GEL2150
Field course and methodology in geology and geophysics

Stratigraphic logging
Identification of seismic boundaries

Scale: 1:15000
UTM Zone 32
Datum: ED50

Exercise

- Make a stratigraphic log, emphasize seismic units/sequences
- Create NW-SE profile
- Calculate thickness of the stratigraphic column using profile
- Convert stratigraphic column to synthetic seismic trace (so you need velocity and density estimates of the lithologies present - literature)
- Correlate your seismic trace with seismic from the Skagerrak
- Interprete OG-7 using what you have learned during this exercise

Report

- **Introduction**
  - Shortly about the approach to the problem
  - Figures: Location of the research area
- **Geological Framework**
  - Short introduction to the geology of the Oslo Region
  - Figures: Map
- **Procedure**
  - What did you do to get the results
  - Figures: up to you
- **Results and discussion**
  - Compare the field results with the seismic from the Skagerrak
  - Figures: stratigraphical column, ”synthetic seismogram”, interpretation of seismic.
- **Conclusions**
  - Main results – what have I learnt….?
- **References**