GEL2150: Field course and methodology in geology and geophysics

Introduction to Geophysical exercise

Course teachers: Michel Heeremans, Jens Jahren and Johan Petter Nystuen

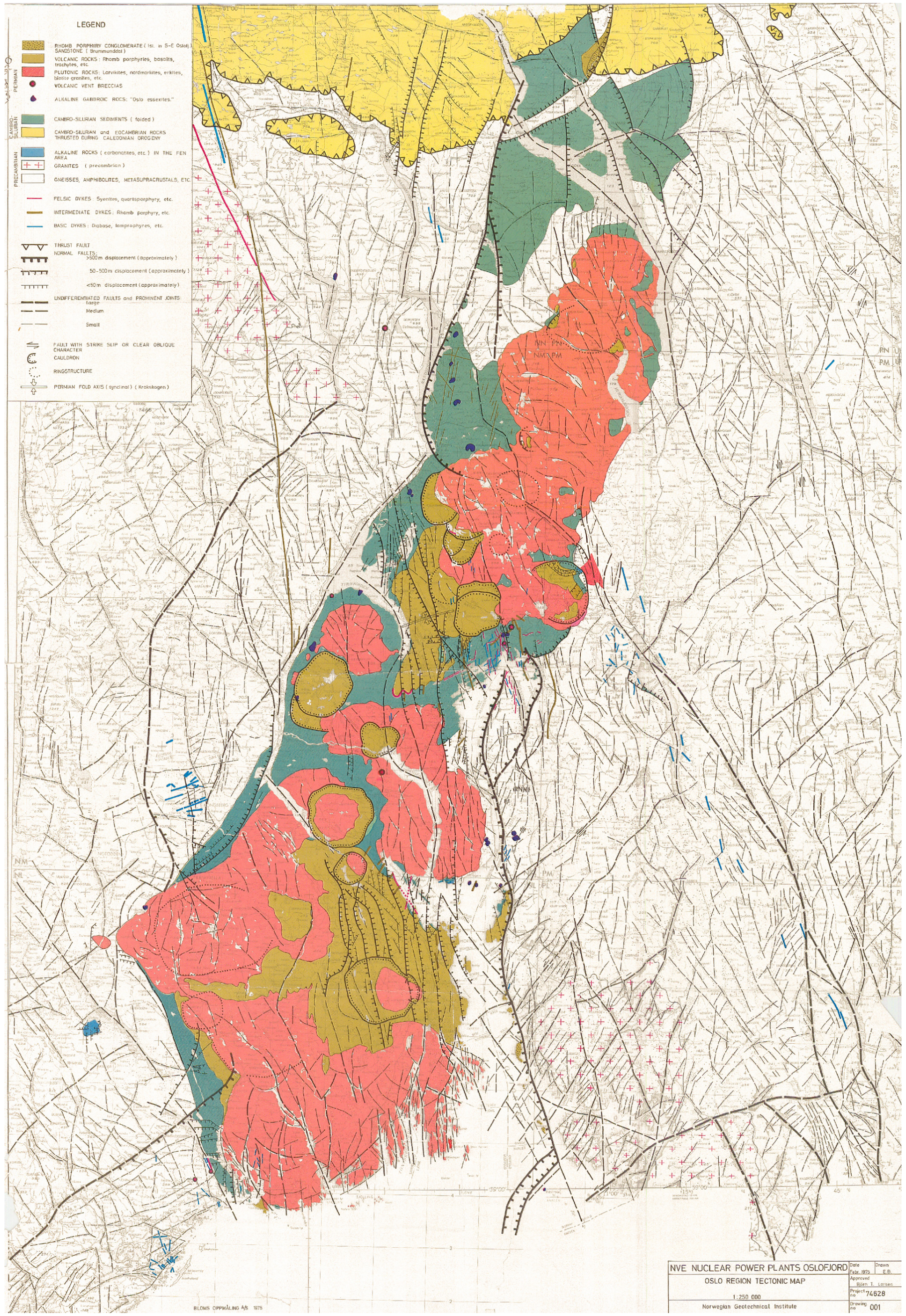
Purpose of the course

- Give an example of how to apply the seismic method in practice
  - Apply theoretical knowledge in the field
- Make you familiar with logg/well-to-seismic correlation

Contents

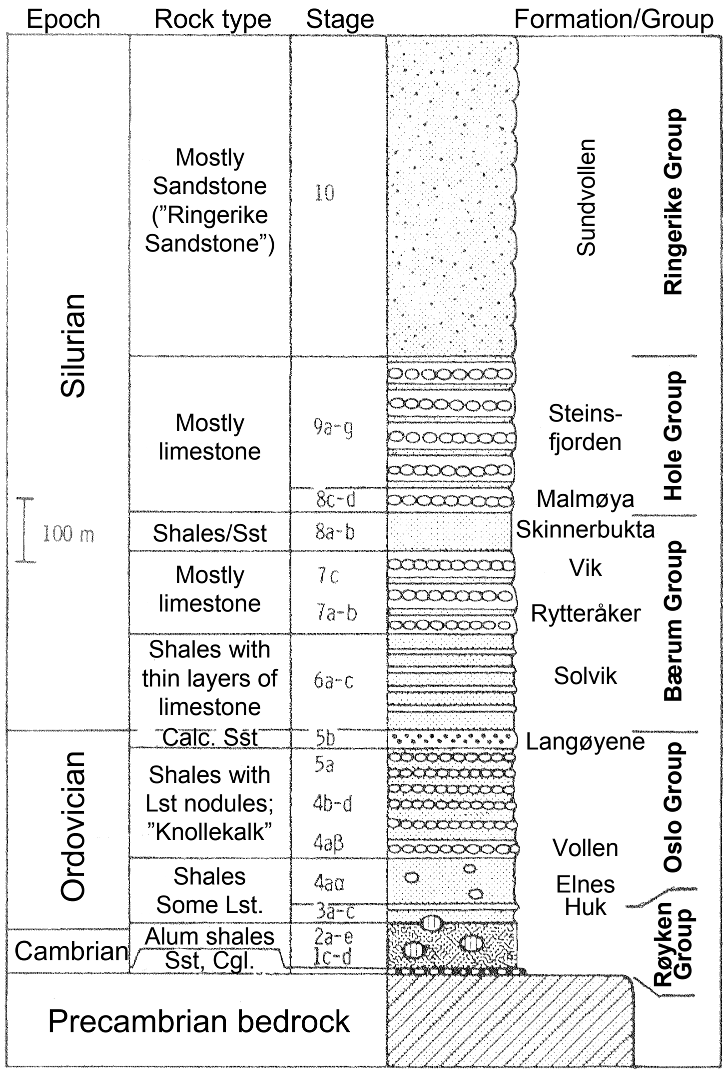
- Geology of the Oslo Rift
- Stratigraphic logging in the field
- Synthetic seismograms
- Introduction to determination of acoustic impedance in the field
- Correlation between stratigraphy and seismic
- Report

Oslo Graben

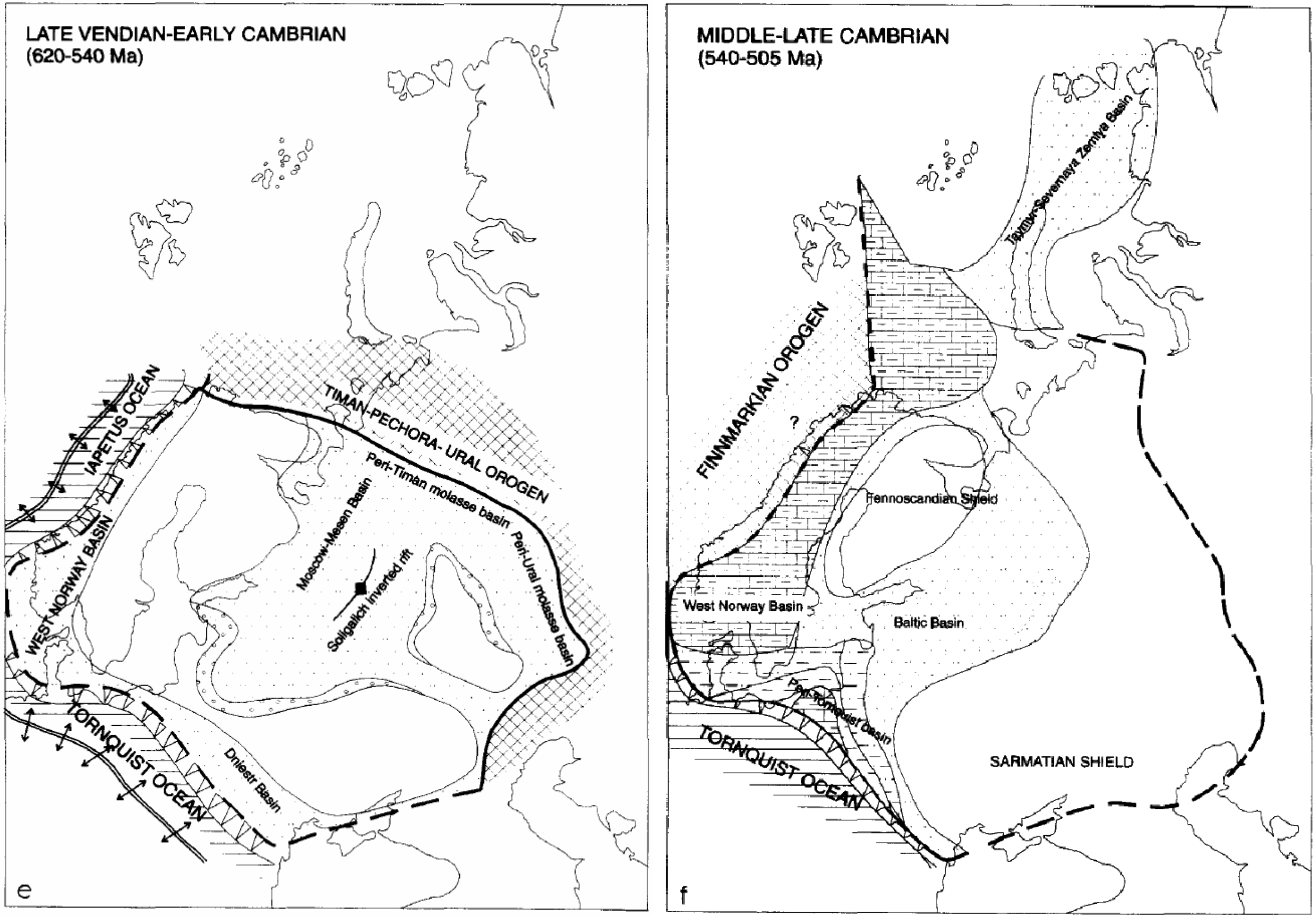


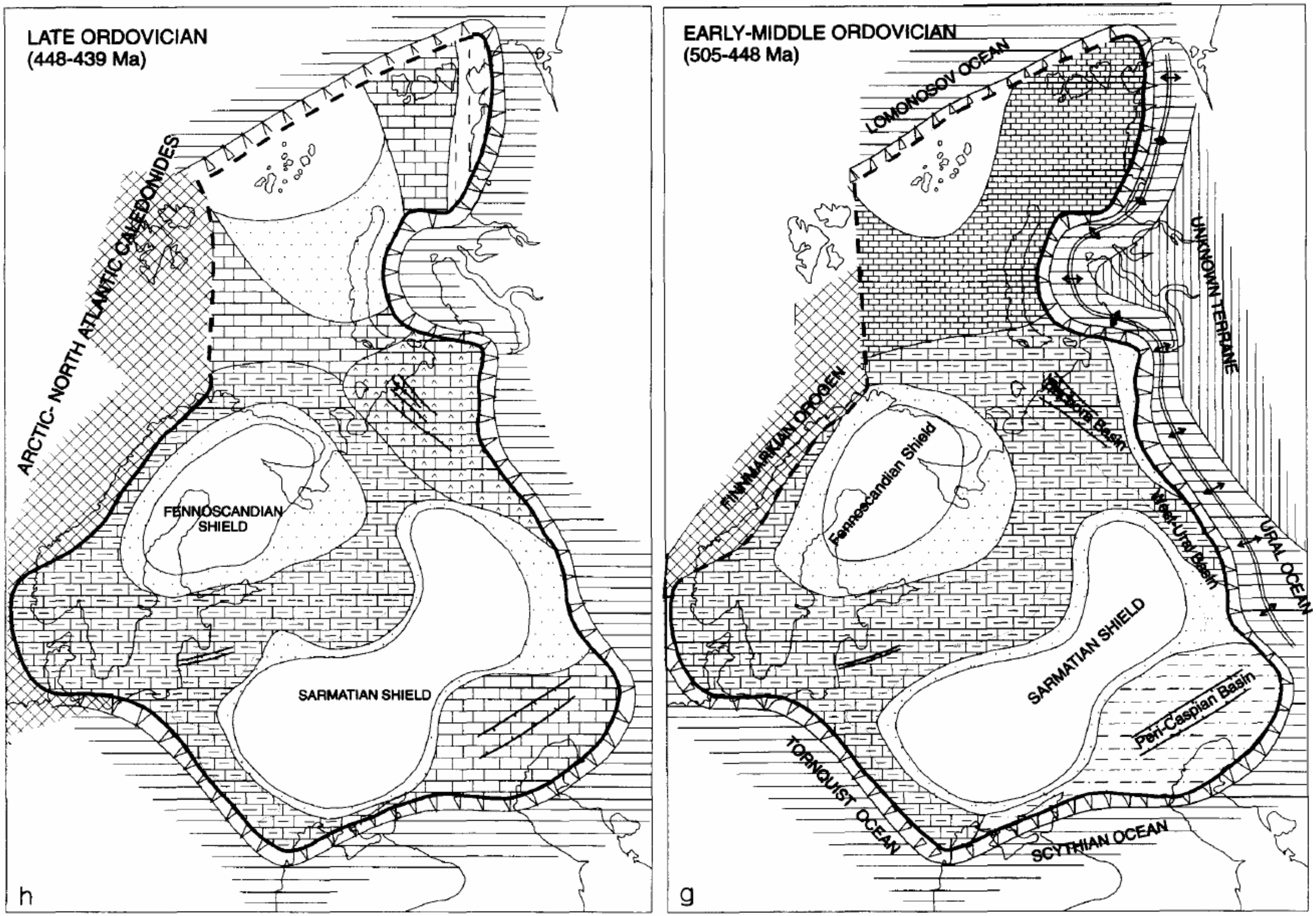
- Active between c. 320 – 240 Ma
- Preserved Cambro-Silurian (≥ 1700m)
- Upper Carboniferous Asker Group (70-80m)
- U-Carb. – Permian igneous rocks (basalts/RP & intrusives)
- Permian sediments

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
TIMAN-PECHORA- URAL OROGEN
Peri-Timan molasse basin
Peri-Ural molasse basin
Moscow-Mesen Basin
Soligalich inverted rift
WEST NORWAY BASIN
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 TERRAINE
FINNMARKIAN OROGEN
Fennoscandian Shield
West-Ural Basin
URAL OCEAN
SARMATIAN SHIELD
Peri-Caspian Basin
TORNQUIST OCEAN
SCYTHIAN OCEAN
g

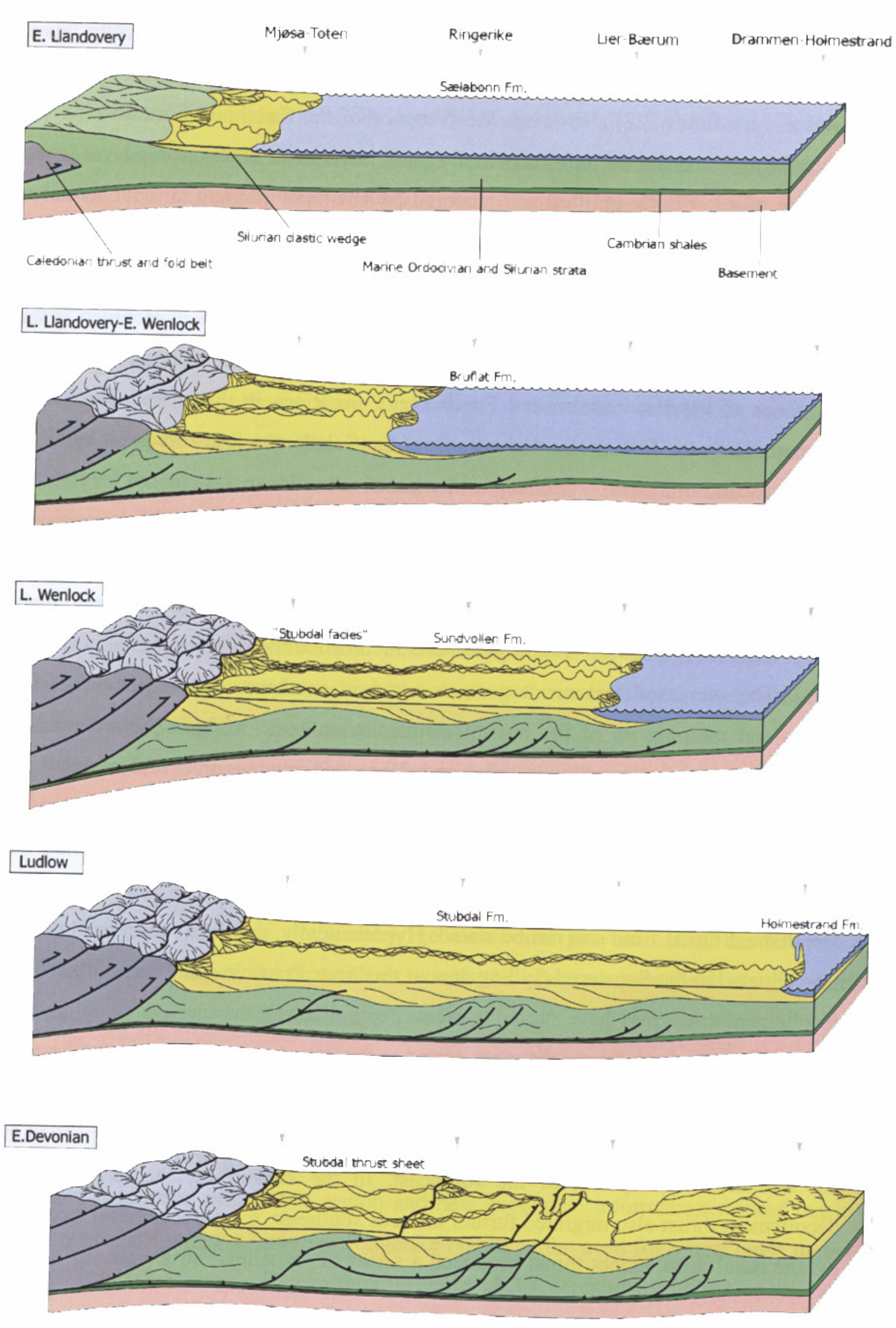
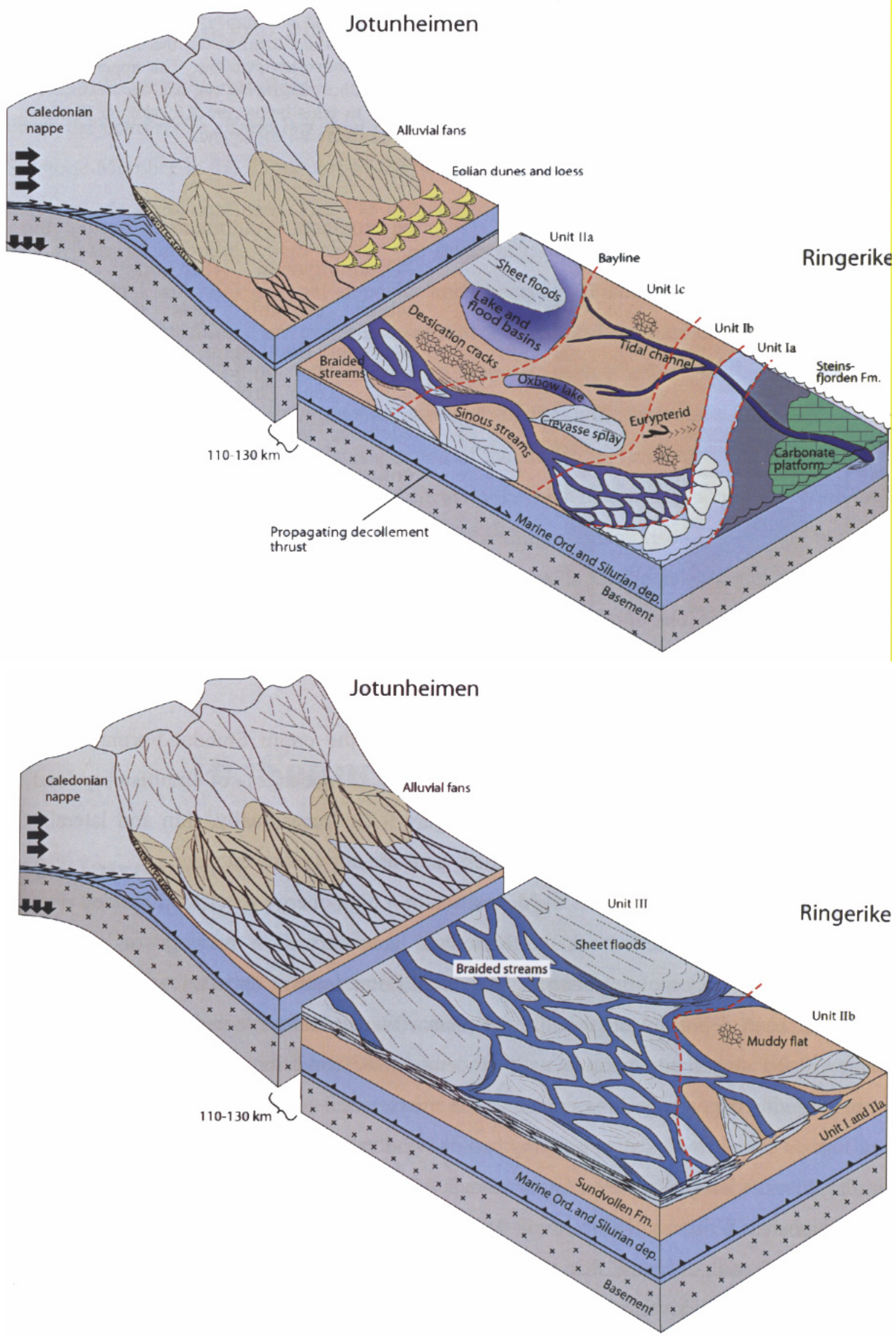
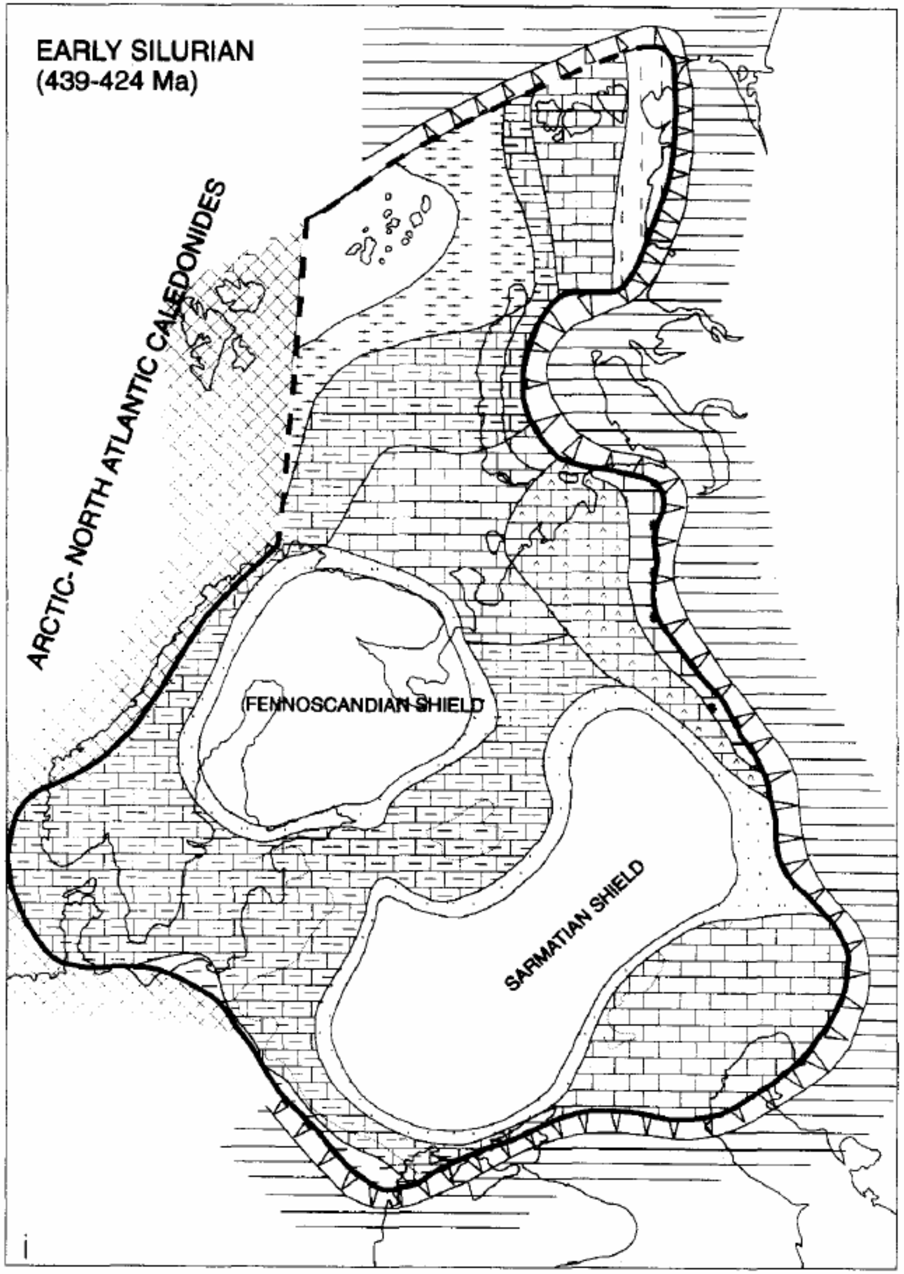
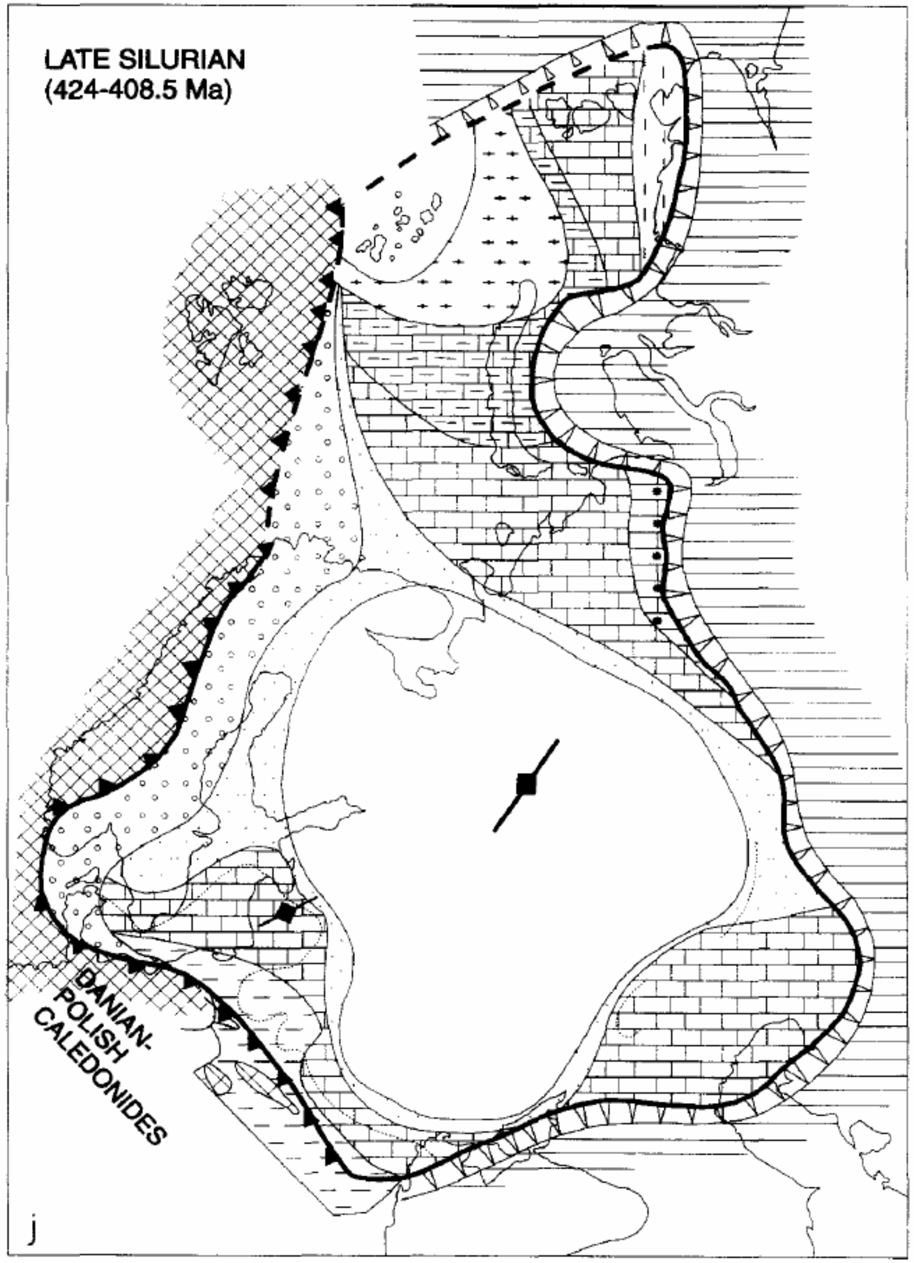


Figure 11.2. Cartoon illustrating the basin evolution and some of the depositional units from Early Silurian to Early Devonian. See text for futher discussion.




EARLY SILURIAN
(439-424 Ma)
ARCTIC- NORTH ATLANTIC CALEDONIDES
FENNOSCANDIAN SHIELD
SARMATIAN SHIELD
i


LATE SILURIAN
(424-408.5 Ma)
DANIAN-
POLISH
CALEDONIDES
j

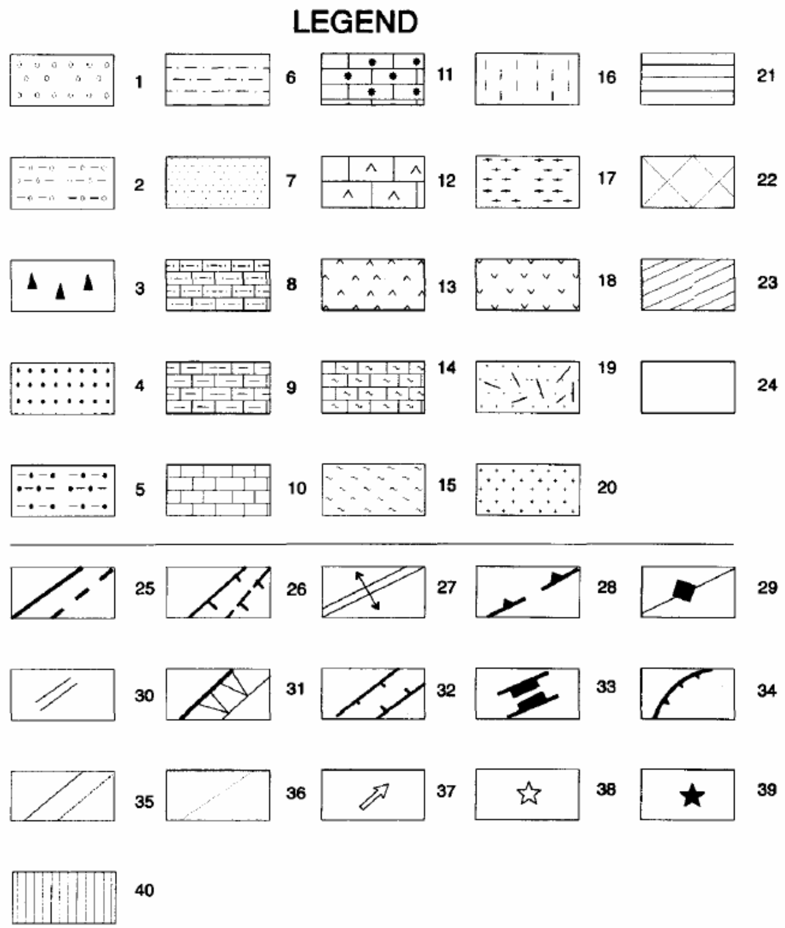
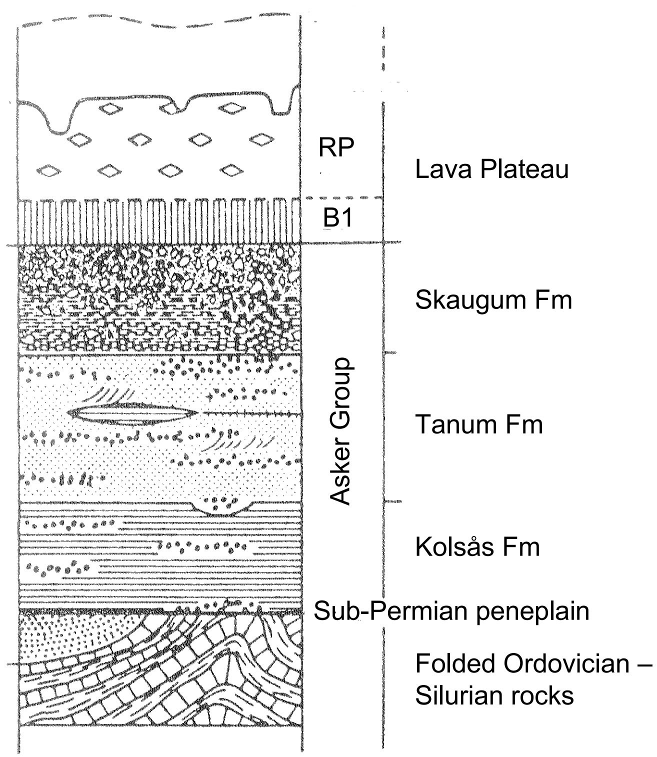


Fig. 7. **Palaeotectonic/palaeogeographic** maps of the East European Craton. Legend: *1* = continental sands; *2* = continental sands and shales; *3* = tillites (Early Vendian); *4* = alluvial-deltaic and shallow-marine, mainly sands; *5* = alluvial-deltaic and shallow-marine sands and shales; *6* = 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.

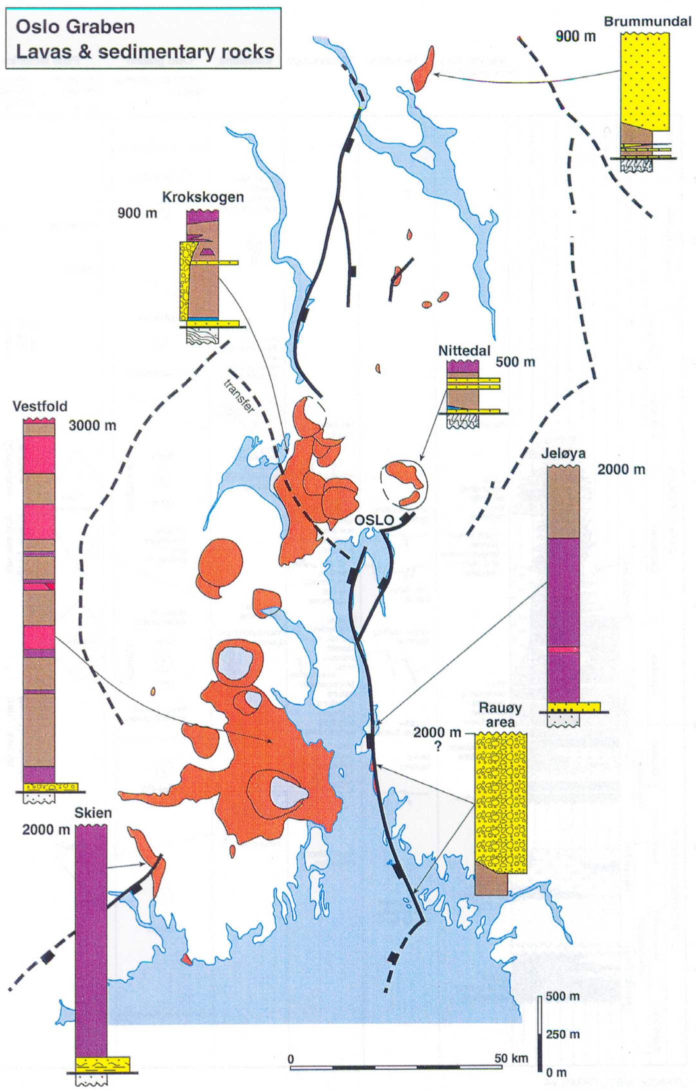
Upper Paleozoic sediments

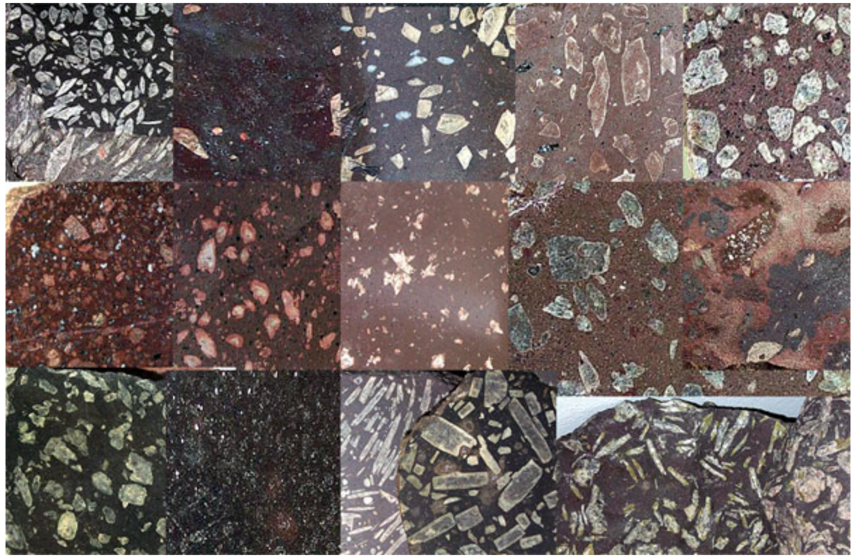
Krokskogen, Tyrifjorden



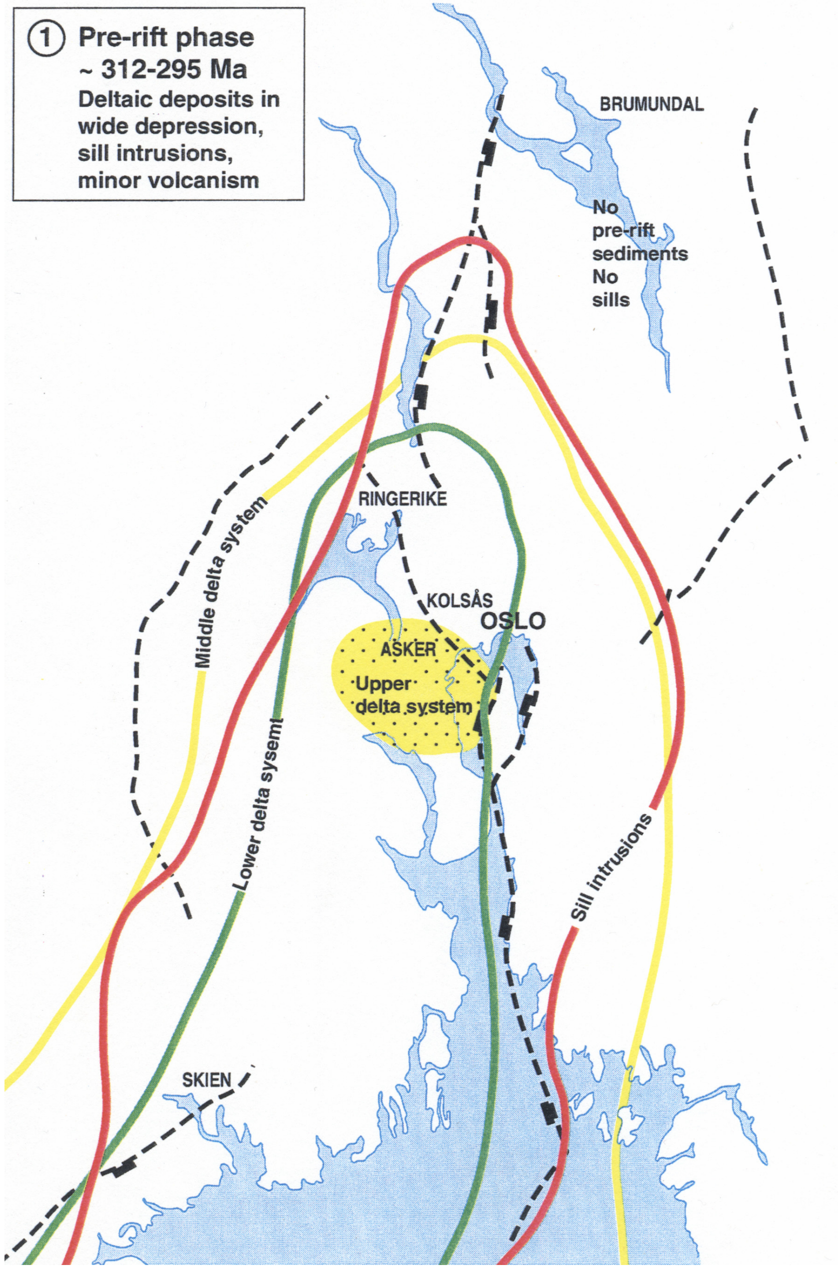
- Asker Group
  - Deposited on a eroded peneplain (20° North)
  - Continental deposits (rivers, deltas)
- Kolsås Fm
  - Red shales; some sst and lst; 15m
- Tanum Fm
  - Sst and Cgl; lst as cement; 15m
  - 1m thick marine lst
- Skaugum Fm
  - Red shales and sst; volcanic detritus; 20m

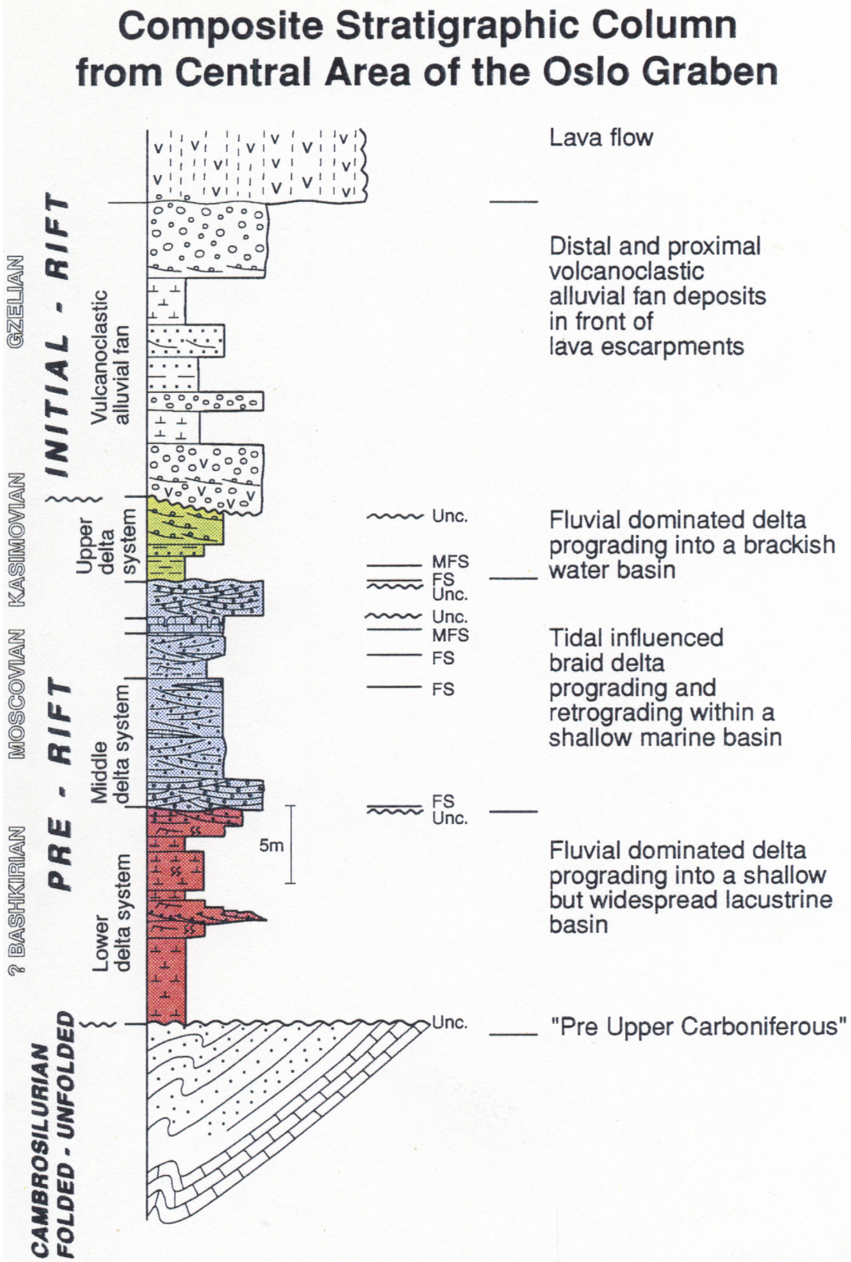
Upper-Carboniferous – Permian lavas and sedimentary rocks



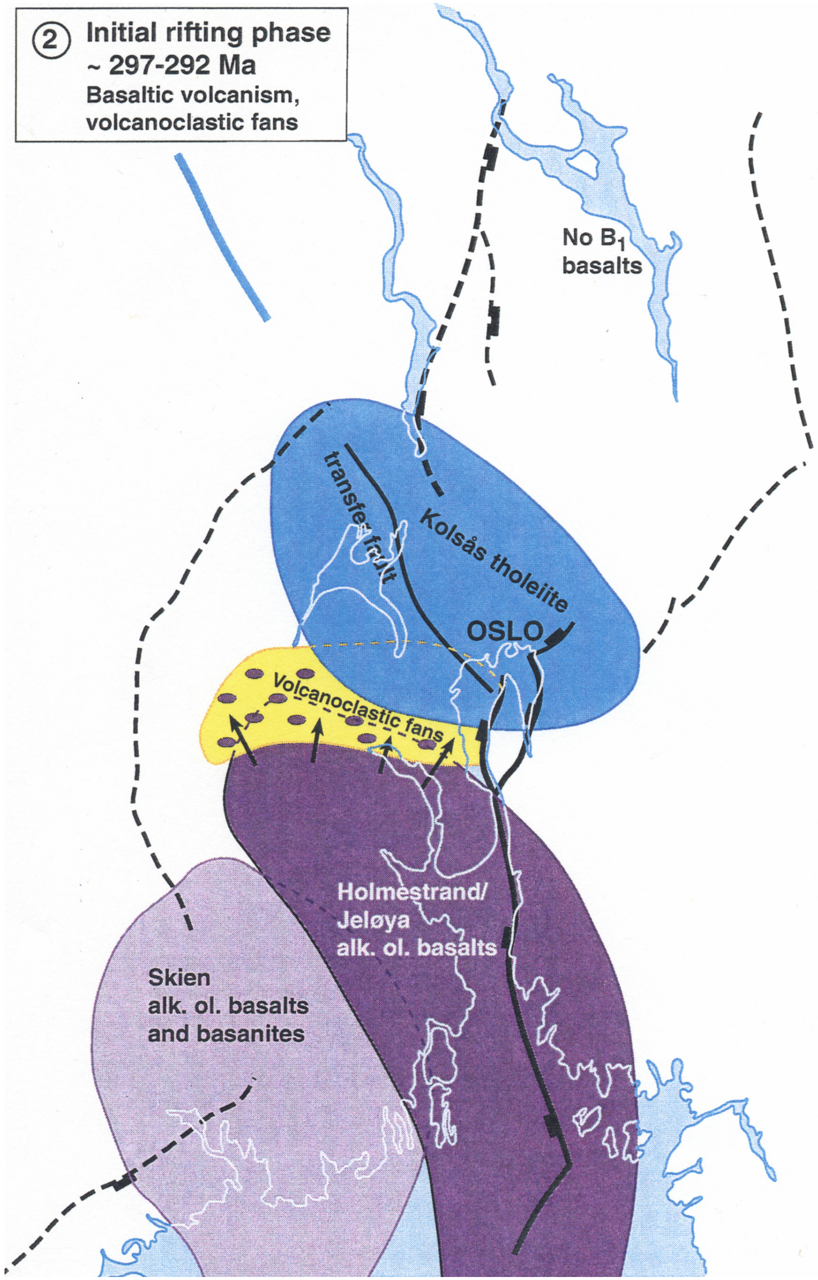


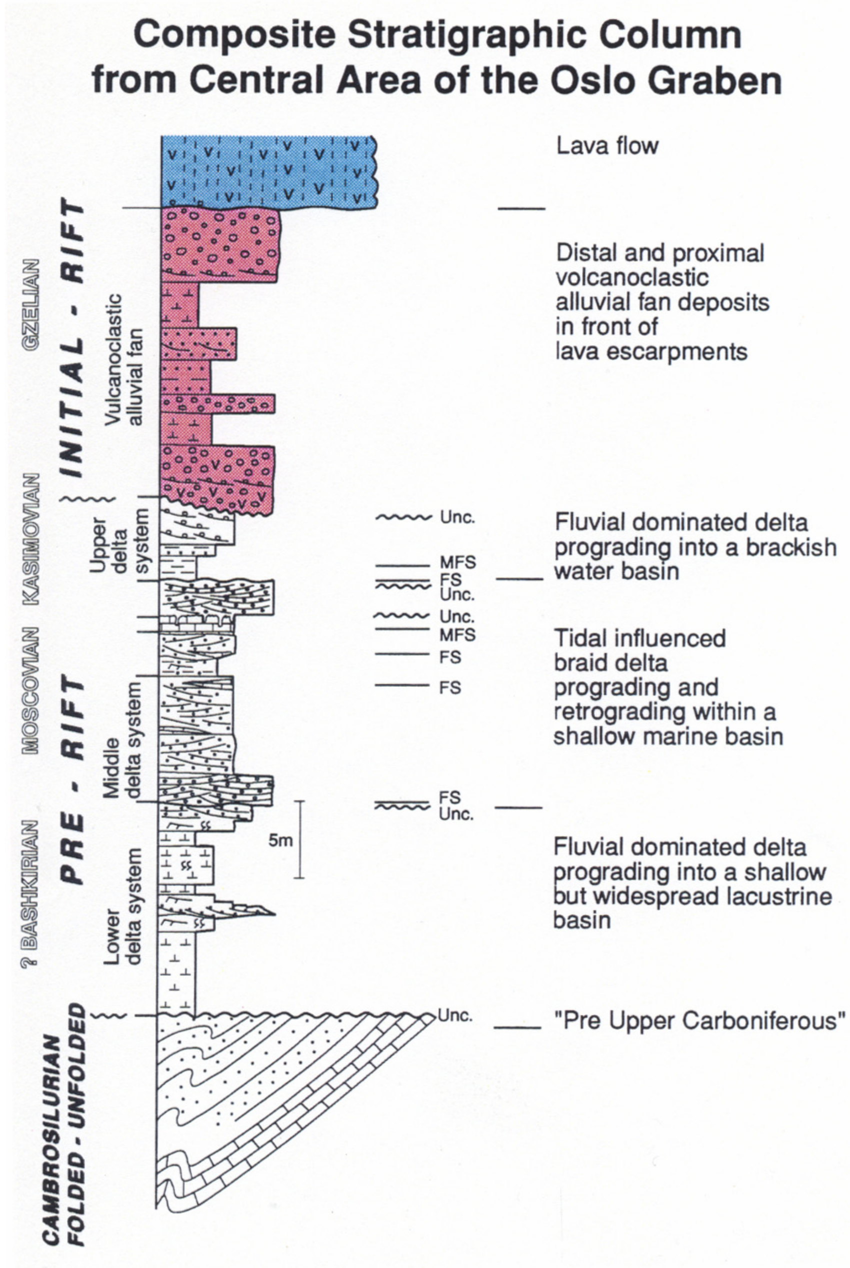
Graben Formation



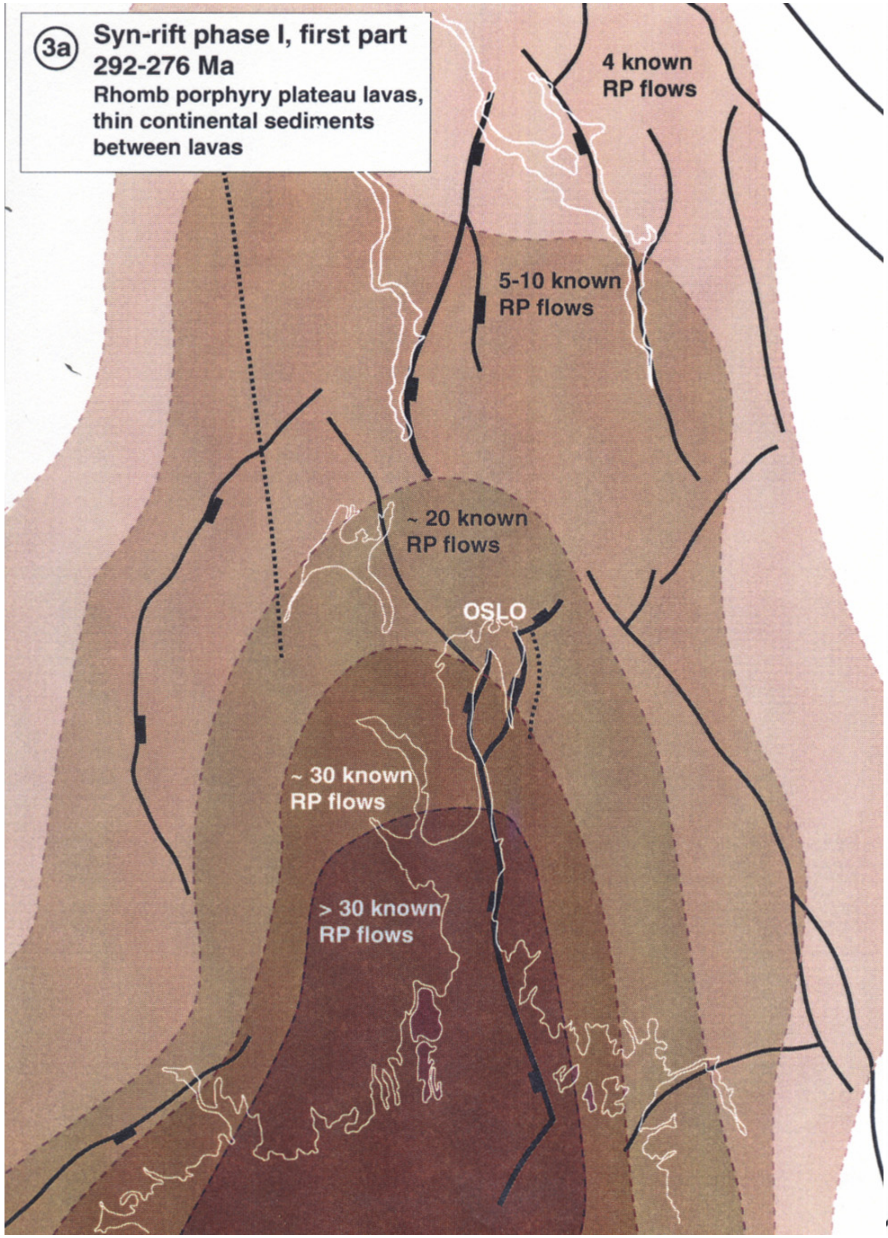


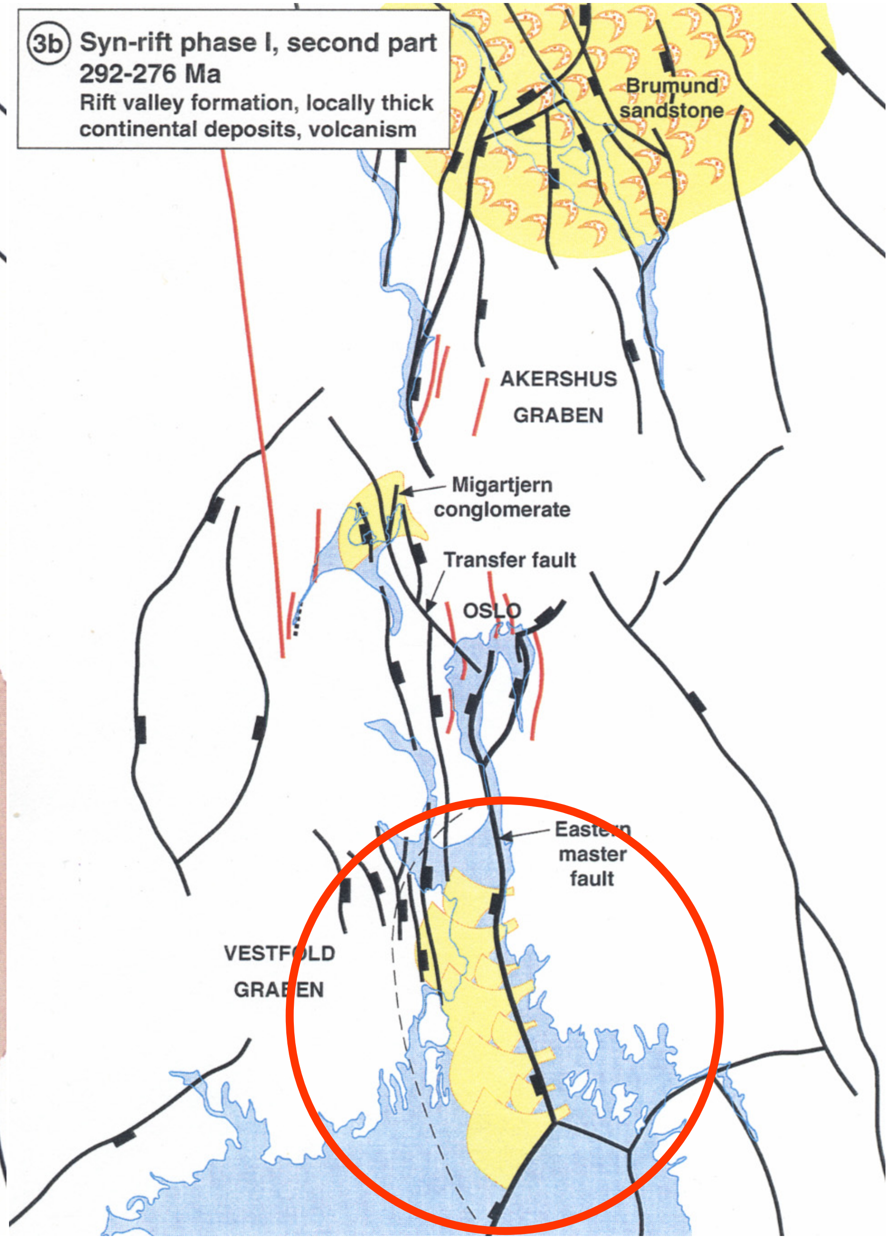
Graben Formation

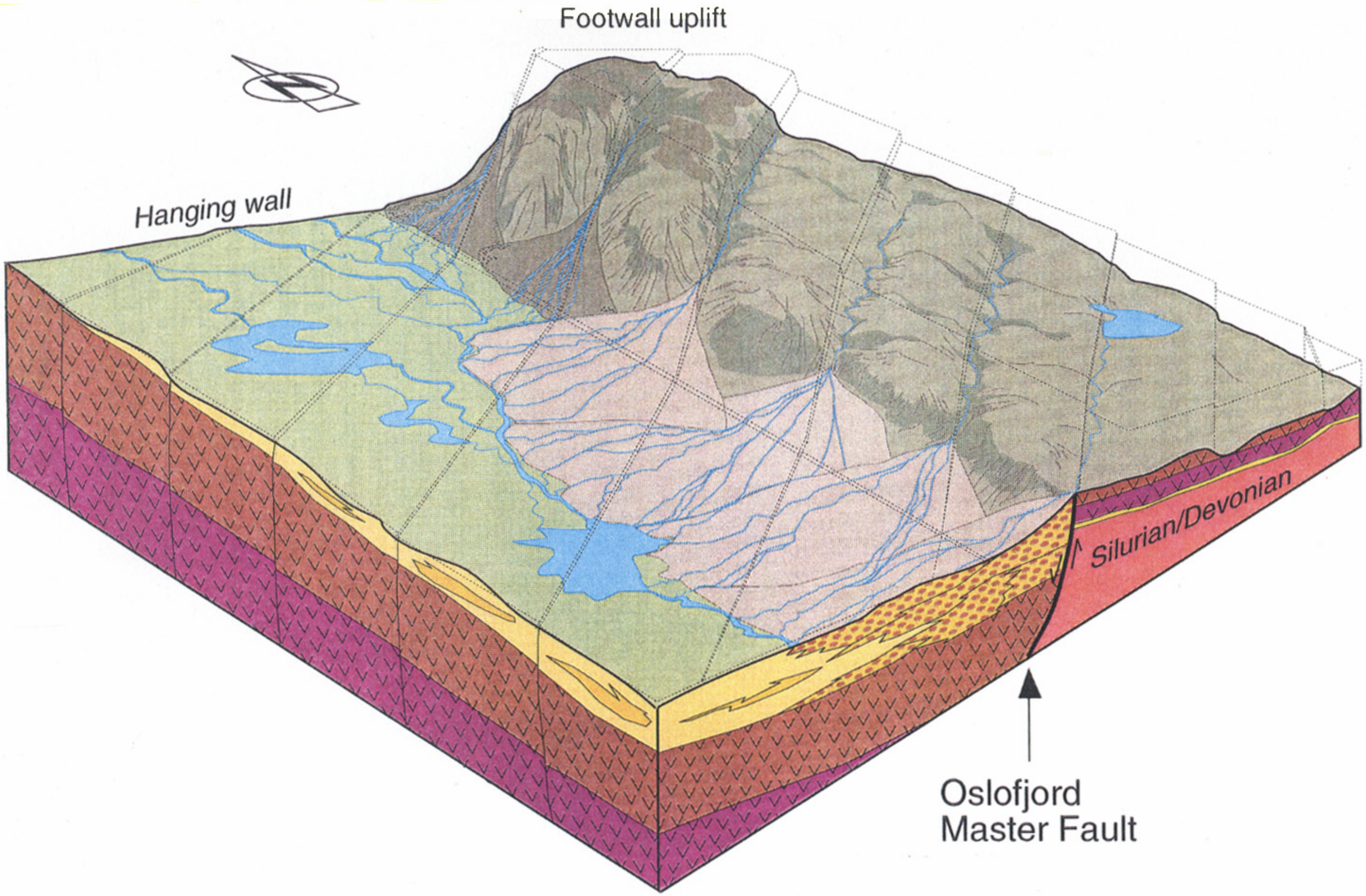




Graben Formation

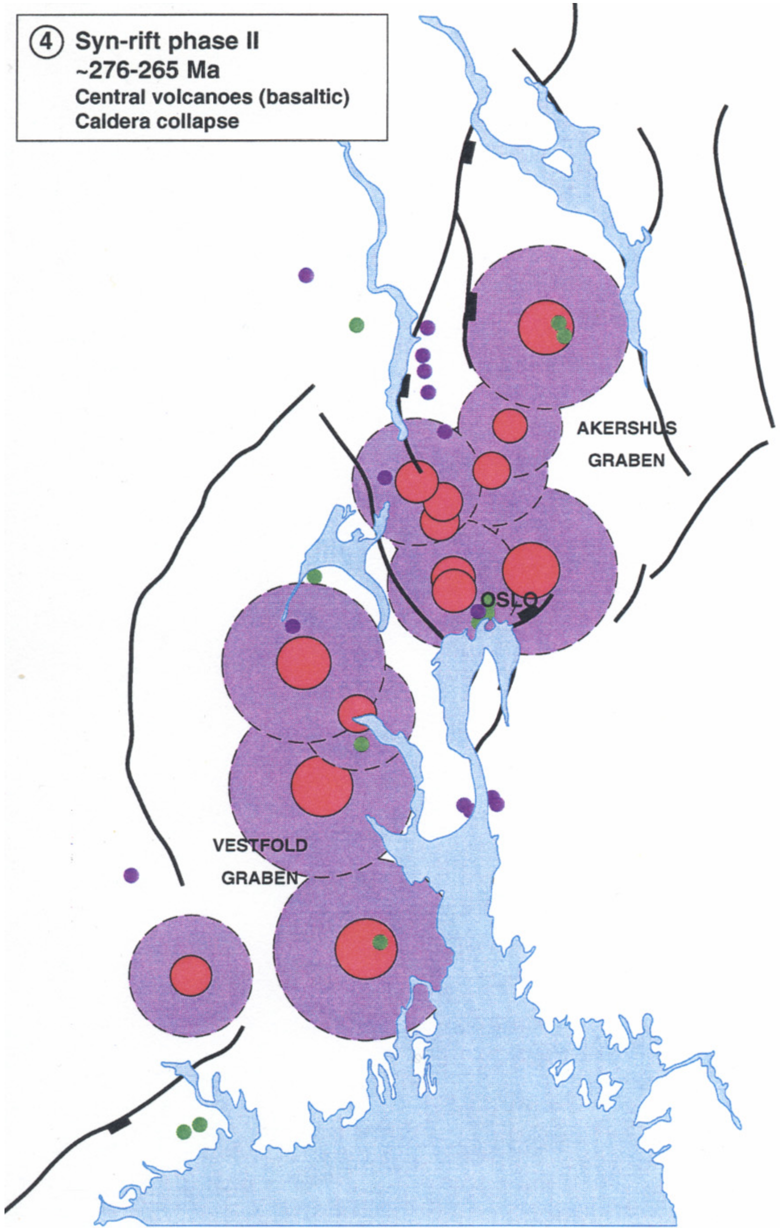


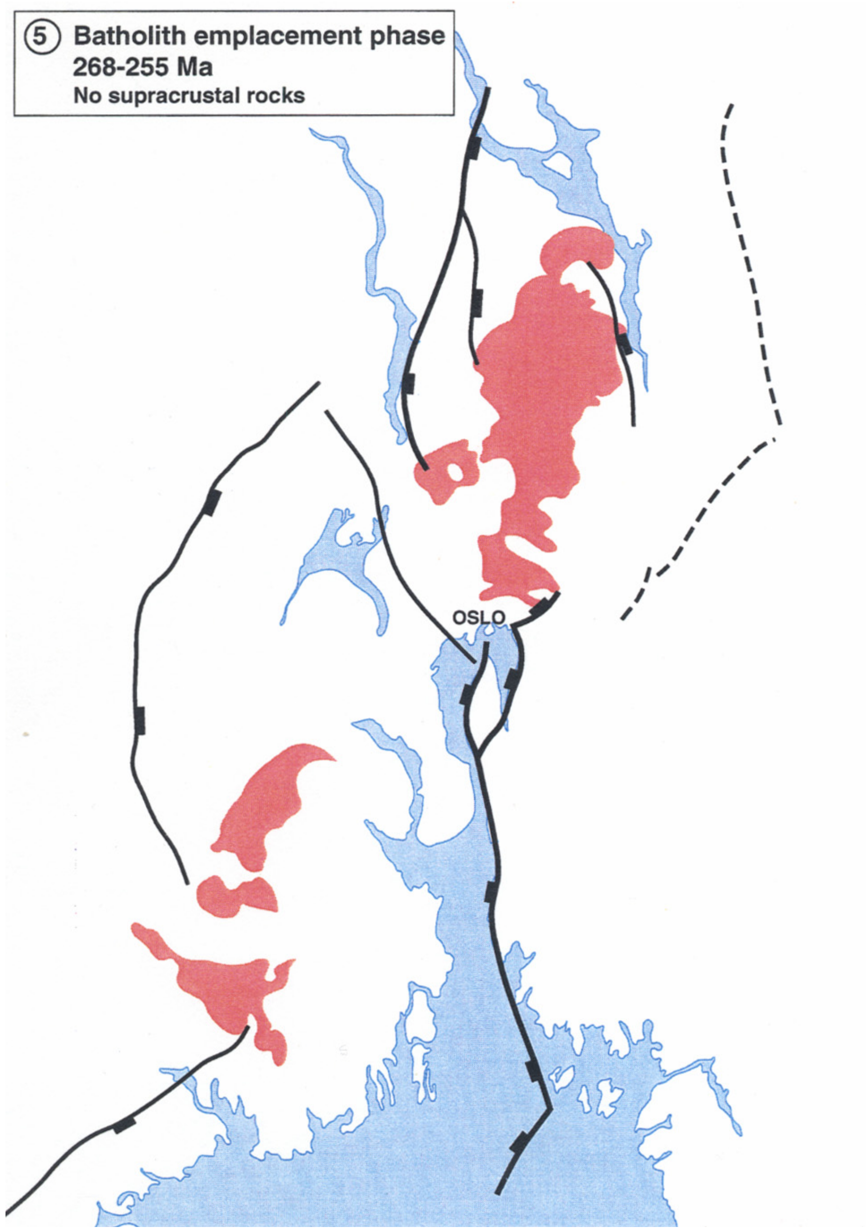


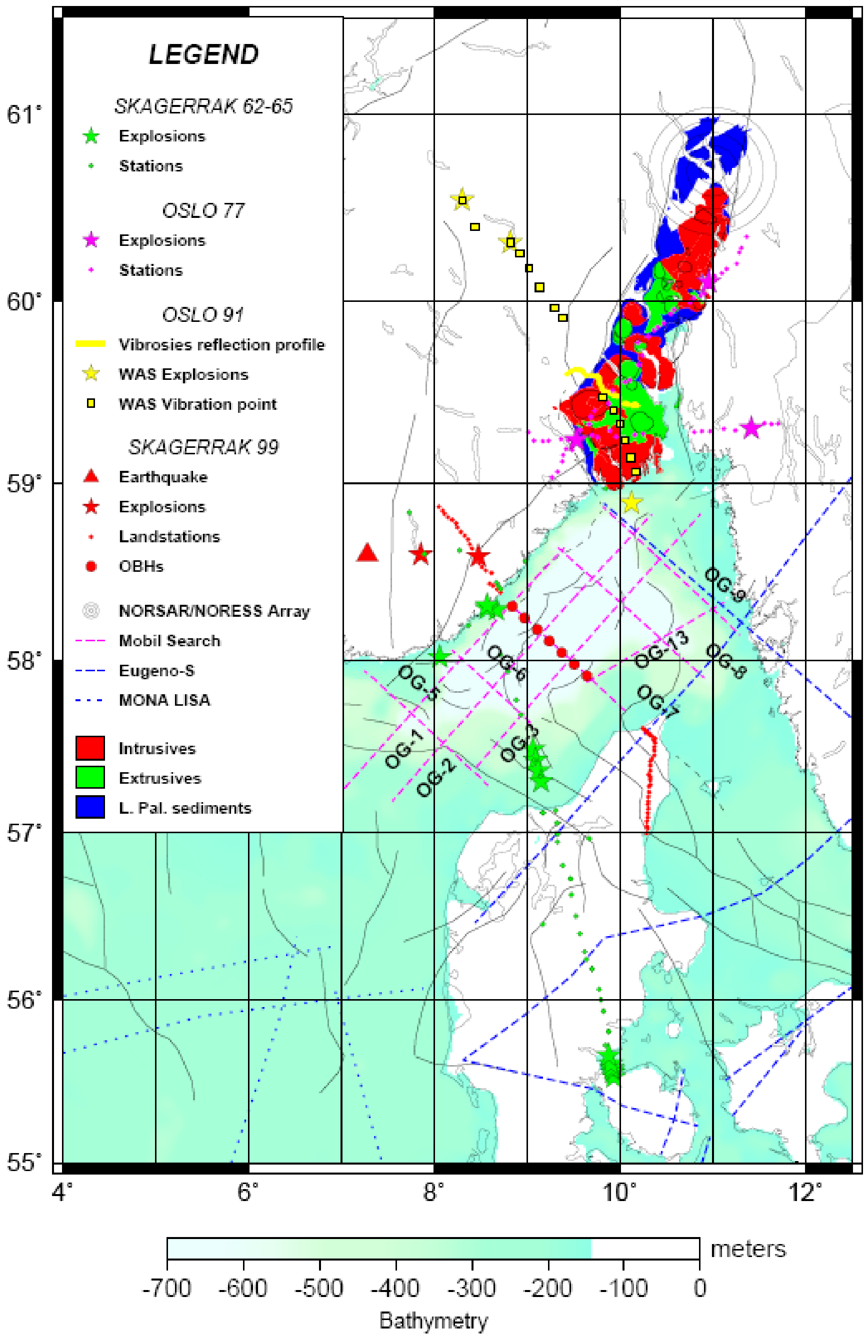


Thick volcaniclastic alluvial fans banked against the master fault

Graben Formation



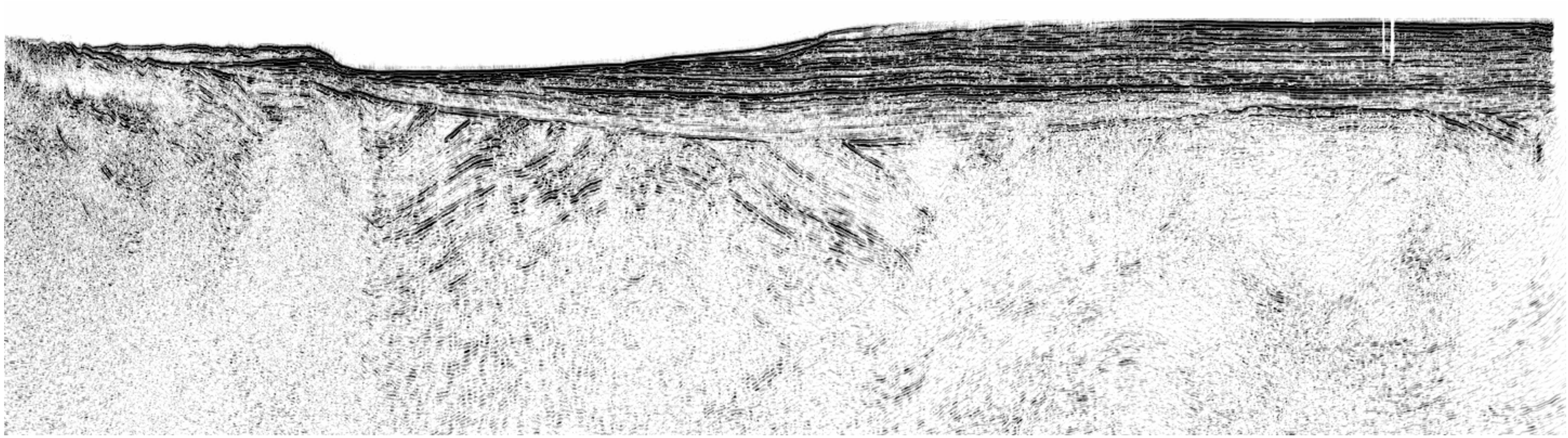




Correlation between Oslo Graben and Skagerrak Graben

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

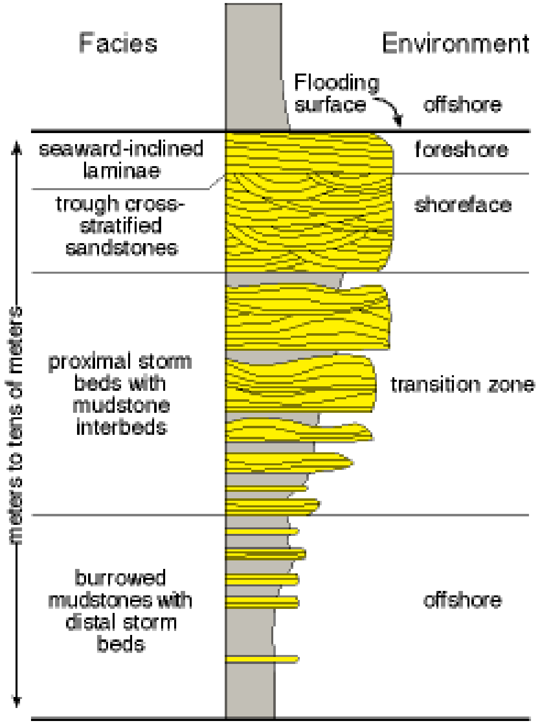
Seismic line OG-7

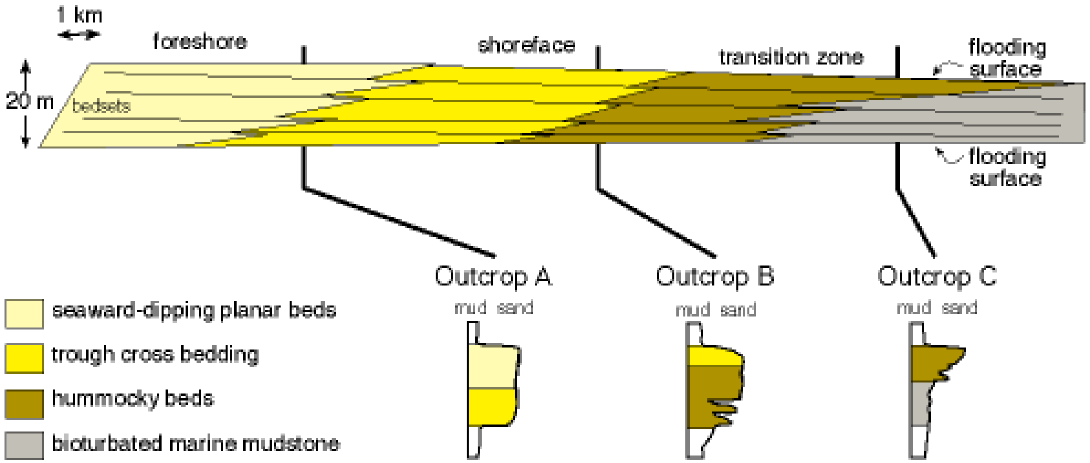


How to correlate OG and SG

- 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?

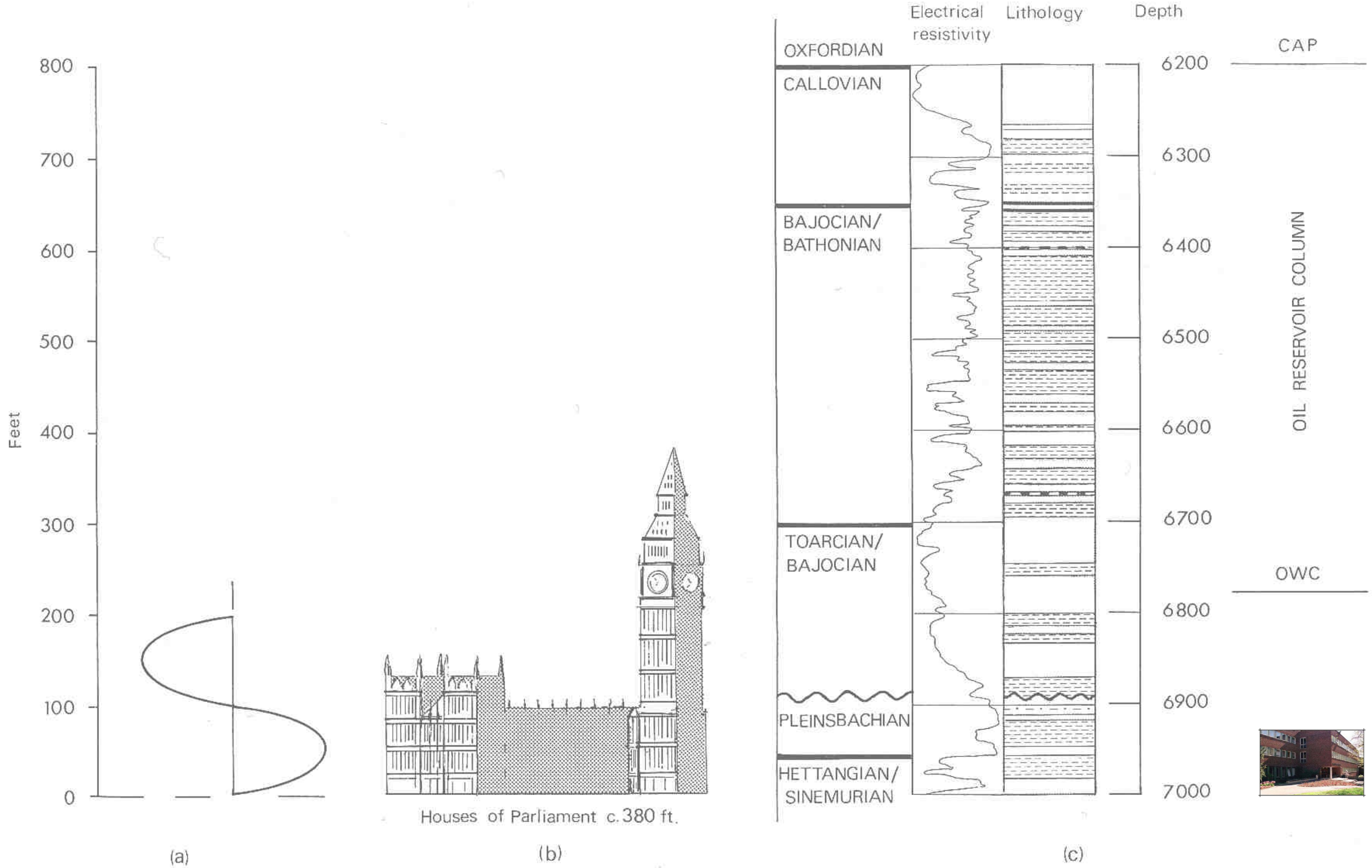
Seismic scale

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

				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



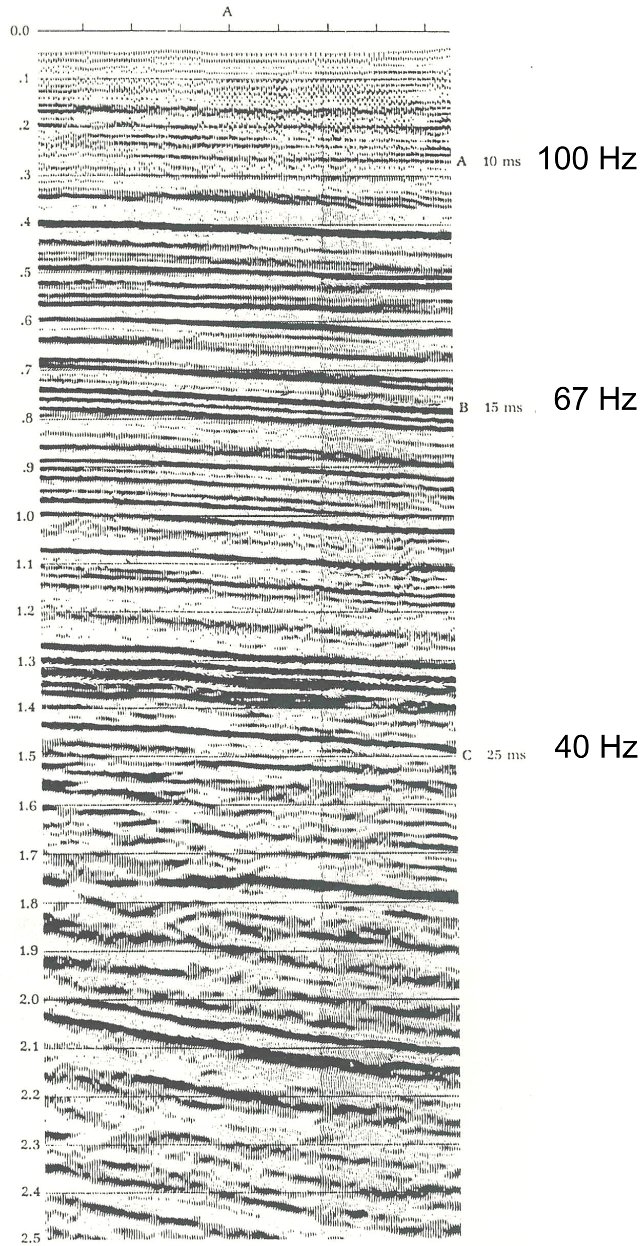
Vertical resolution

Wavelength increases with depth
Frequency decreases with depth

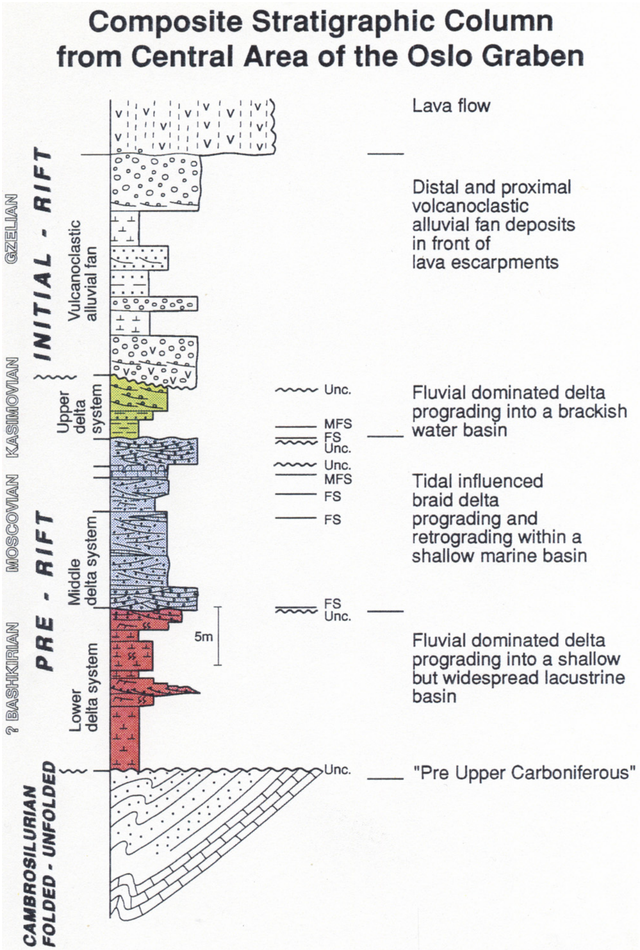
↓

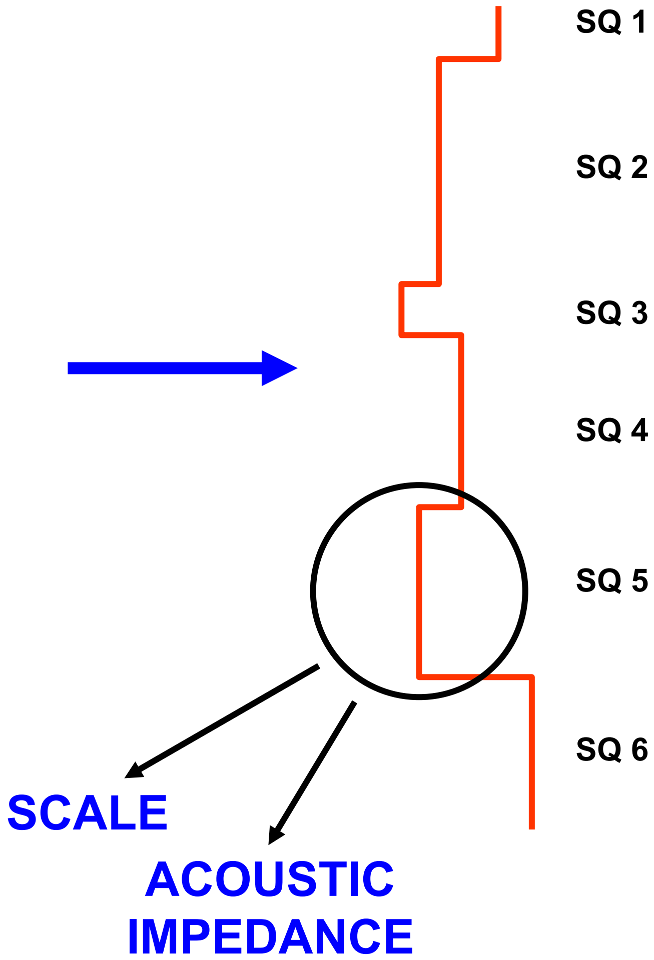
Reduced vertical resolution

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



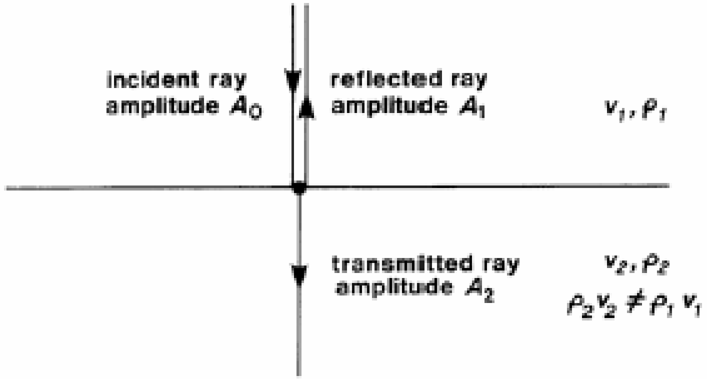
Seismic sequences

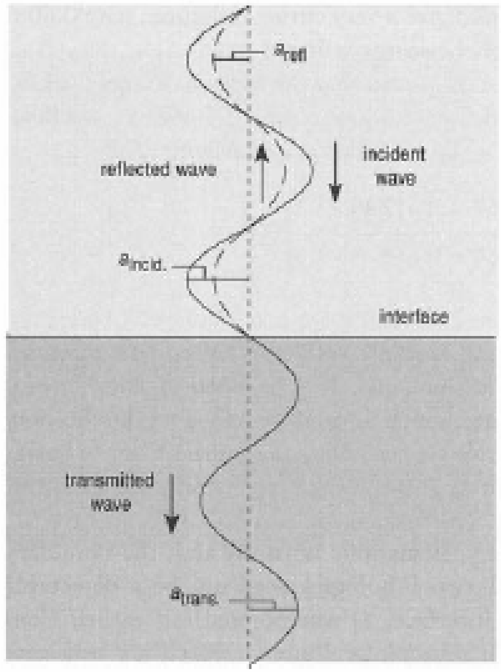




WHAT IS A REFLECTOR: HOW CAN IT BE DEFINED (how strong it is)?

Normally Incident Seismic Rays





acoustic impedance $Z = \rho v$

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

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

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

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

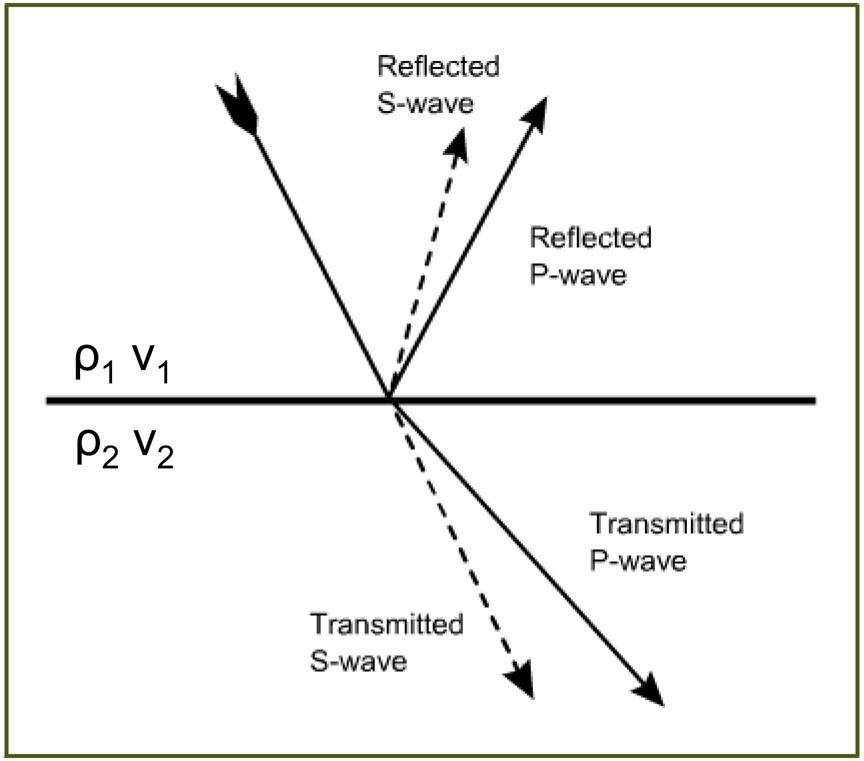
$-1 \leq R \geq +1$

$R = 0$ ⟶ *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*

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.



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

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

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

Expressions are for vertically incoming pressure waves.

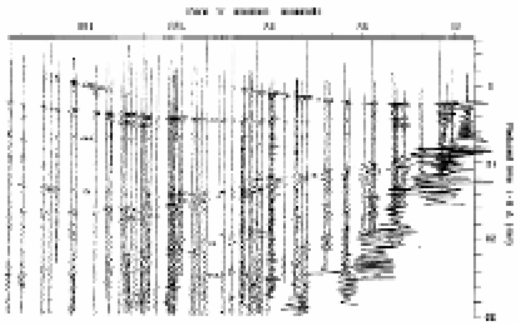
Acoustic impedance: ρ v

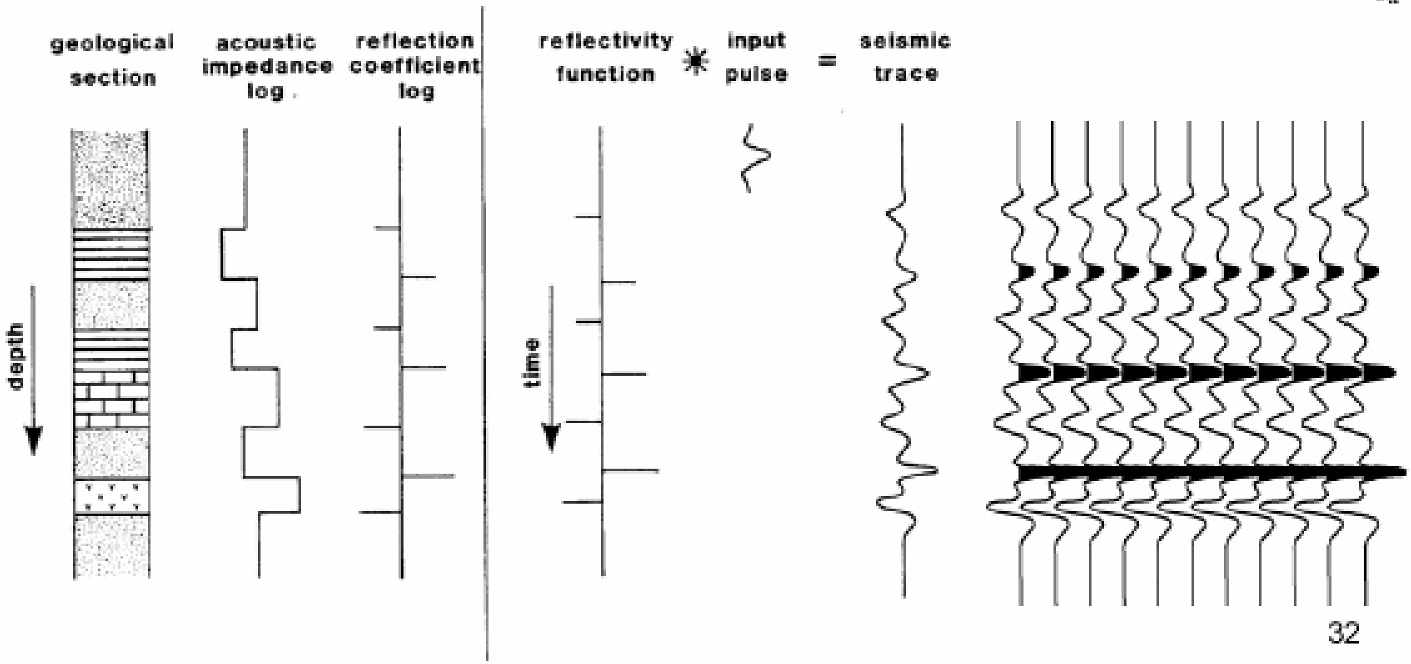
Acoustic impedance is the product between the wave velocity and the density of the medium. I=ρv

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

SEISMIC TRACE (REFLECTION SEISMOGRAM)

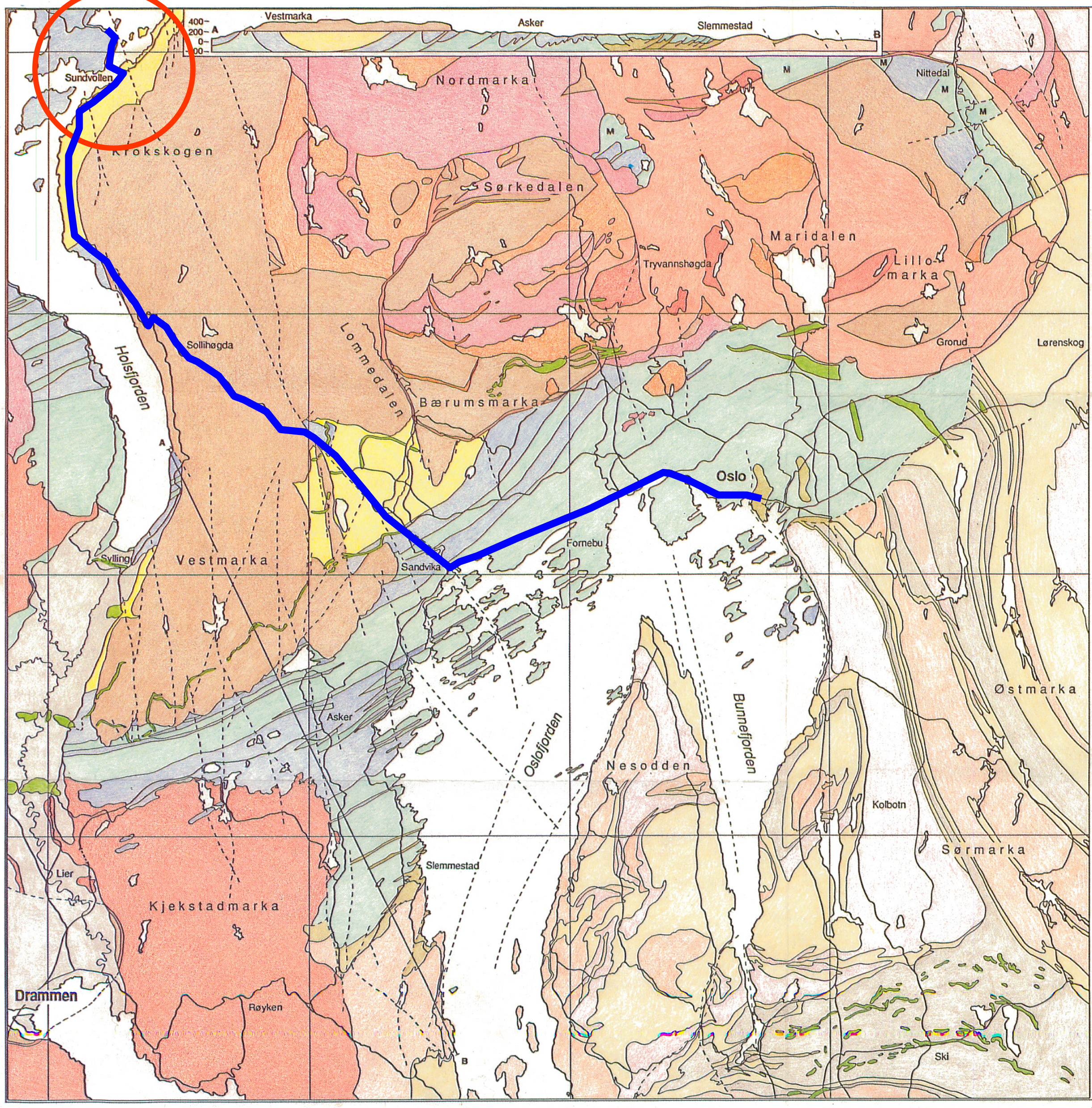
***Seismic trace**:*
amplified oscillographic recording of each detector (geo-/ hydro-phone)





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

Sammenstillet av Johan Naterstad, 1991

Målestokk: 1:150 000

0 1 2 3 4 5 6 7 8 km

Tegnforklaring og kommentarer:

Kvartær

- Grus og sand i israndavsetninger og endemorener
- Marin leire og noe sand og grus. Avsatt under og etter siste istid. Bare vist på kartet der store masser dekker fast fjell

Området ble isfritt mellom 10100 og 9600 år før nåtid

- Forkastninger og større bruddlinjer. Bare få av de tallrike kaledonske skyveforkastningene er med. Disse er heltrukne på kartet og i snittet

Perm

- Eksplosjonsbreksjer hvor bruddstykketypen varierer. Stedvis forekommer finkornig, felsittisk, syenittporfyr
- Granitt, bl.a. Drammensgranitt (biotittgranitt) og Ekeritt (alkaligranitt). Både grov-, middels- og finkornige typer
- Syenitter, bl.a. Nordmarkitt, Grefsensyenitt m.fl. Dypbergarter av syenittisk sammensetning. Syenitter også i kalderaenes ringganger
- Monzonitt og syenodioritt, bl.a. Larvikitt, Kjelsåsitt, Akeritt. Både grove-, middels- og finkornige typer. Tilførselsrør for en vulkan i Ullernåsen

Karbon Perm

- Basaltlavaer og rombeporfyrlavaer i veksling. Sedimentære bergarter underst og mellom mange av strømmene

Innenfor kartet finnes flere ringstrukturer, bl.a.tre eroderte kalderaer som skjærer bergarter av ulik alder: Drammen-k., Bærum-k., Nittedal-k. Tallrike eruptivganger i hele området

Silur

- Sandstein. Rød eller grå-hvit, opprinnelig avsatt som sand i brakkvann / ferskvann
- Kalkstein er det mest av i disse havavsatte siluriske sedimentene. Ofte som knollekalk. Skifer med mange kalklag er også vanlig

Ordovicium

- Kalkstein og leirskifer, lagvis blandet. Knollekalk, kalksandstein og konglomerat. Områder hvor alder er usikker (ordovicium el. silur?) p.g.a. kontaktmetamorfose er merket M

Kambrium

- Leirskifer, mest mørk. Alunskifer, svart, karbonholdig. Konglomerat på grensen til grunnfjellet under

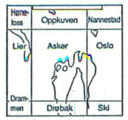
Kambro-silur-lagene er ofte rike på fossiler. Lagene er foldet og skjøvet i devontiden (kaledonsk)

Prekambrium Grunnfjell

- Granitt, rik på kalifeltspat. Ofte grovkornet, og med "øyne" av feltspat. Stedvis øyegneis
- Granitt, rik på plagioklas-feltspat: tonalitt. Svakt gneisomdannet. Viser stedvis tegn til oppsmelting (migmatitt)
- Gneiser, biotittrike, mørkegrå, ofte sliret. Opprinnelig dypbergarten granitt. Sterkt deformert
- Gneiser, gjerne lyse og båndete. Opprinnelig overflateavsatte dannelser av sedimentær og vulkansk opprinnelse, mest sandstein og rhyolitt. Deformert

I grunnfjellets gneis og granitt er det ofte mørke partier og bånd av amfibolitt og lyse ganger av pegmatitt

Topografiske kart og forskjellige geologiske kart i målestokk 1:50 000 som dekker området.

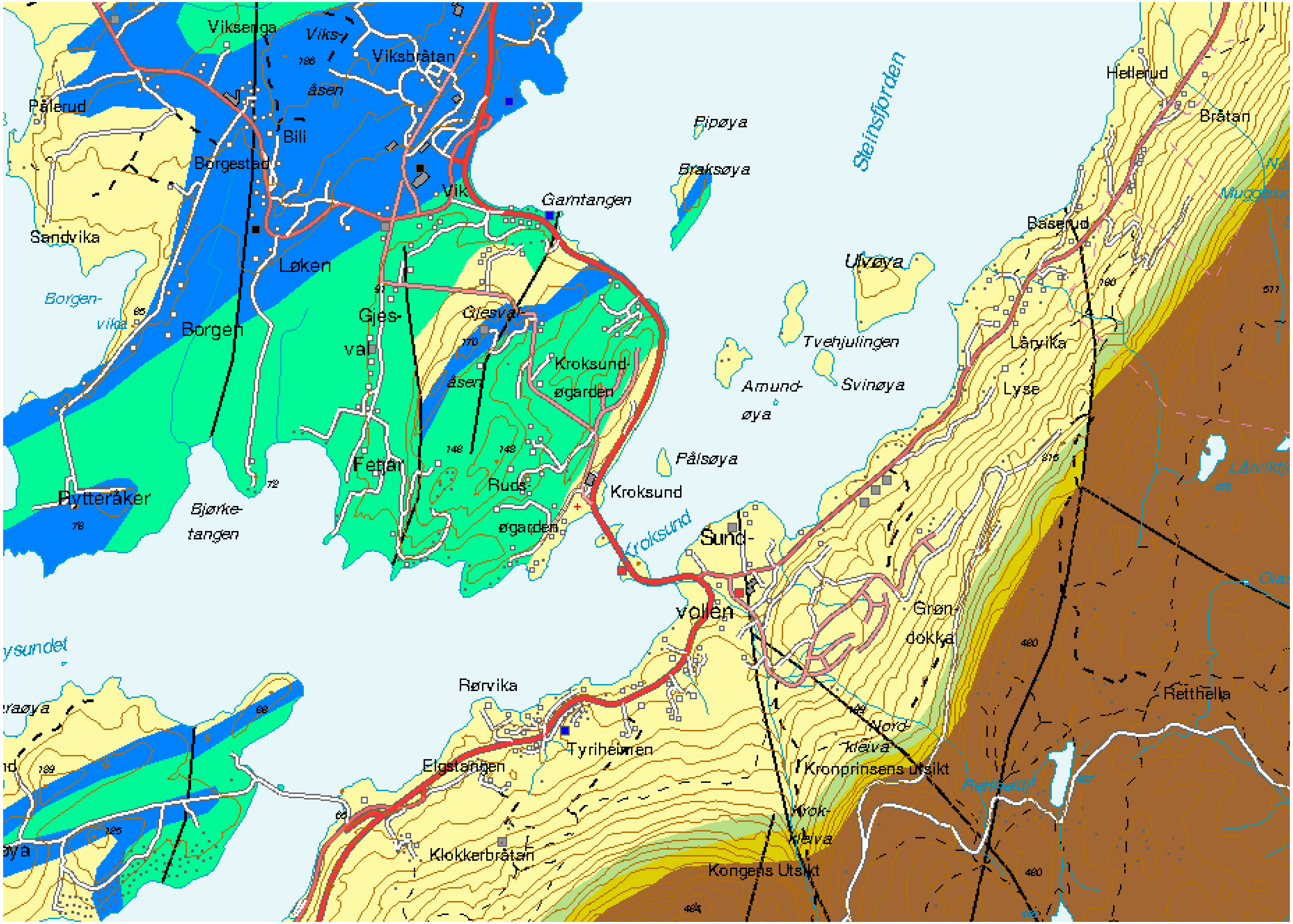


Kartet er sammenstillet ved Skoletjenesten
De naturhistoriske museer
Universitetet i Oslo

Trykking av kartet er bekostet av Norsk Hydro

HYDRO

Vett & Viten as
Postboks 381
N-1301 Sandvika, Norway



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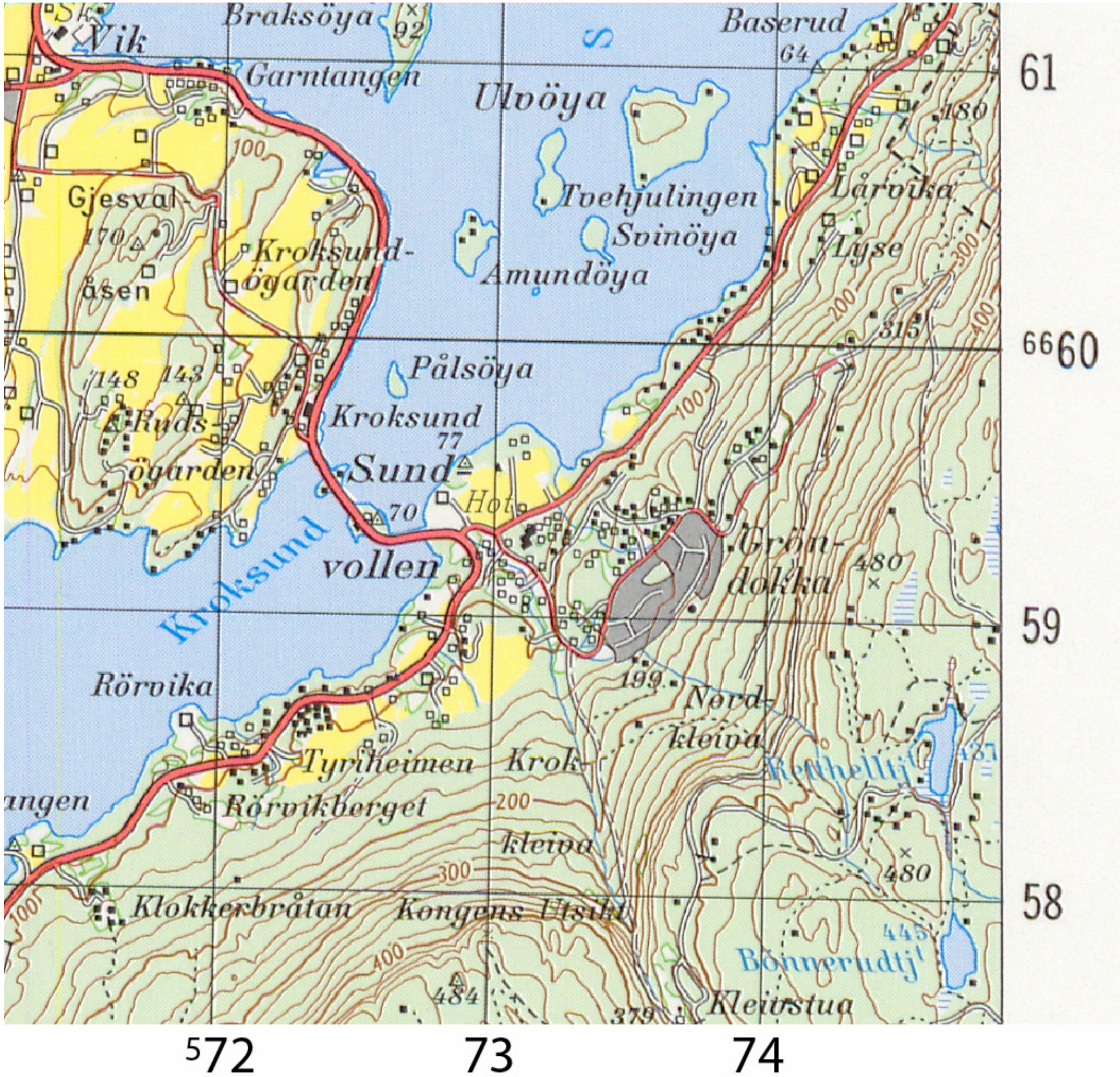

GEL2150
Field course and methodology in geology and geophysics

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**