Figures

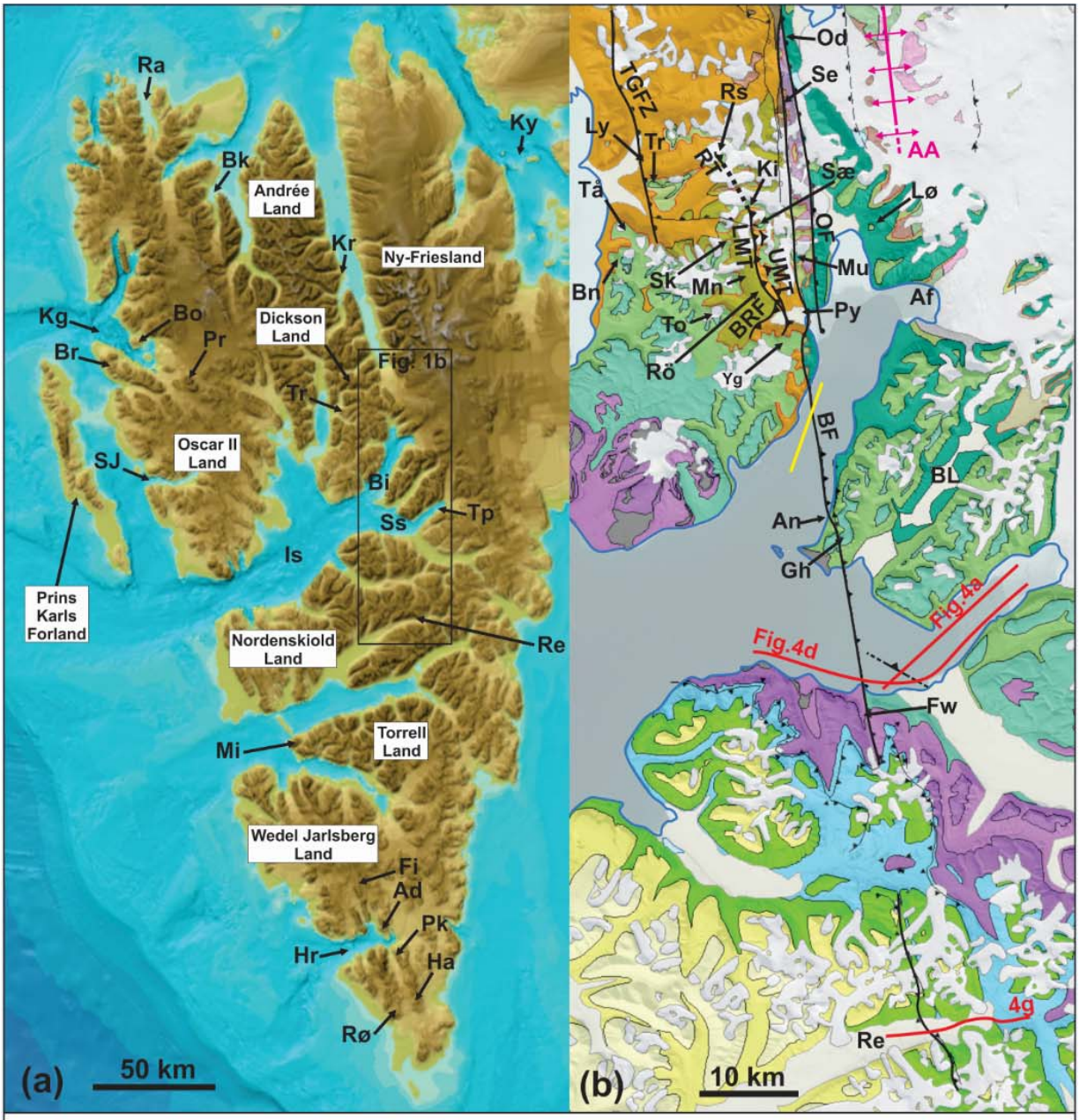

Ra
Bk
Andrée Land
Ky
Kr
Ny-Friesland
Kg
Bo
Pr
Br
Dickson Land
Fig. 1b
Tr
Oscar II Land
SJ
Bi
Tp
Ss
Is
Prins Karls Forland
Nordenskiold Land
Re
Mi
Torrell Land
Wedel Jarlsberg Land
Fi
Ad
Pk
Hr
Ha
Rø
(a)
50 km
Od
Se
TGFZ
Rs
Ly
Tr
AA
Pt
Ki
Sæ
Tå
Lø
LMT
UMT
Mu
Bn
Sk
Mn
Af
To
BRF
Py
Rö
Yg
BF
BL
An
Gh
Fig.4a
Fig.4d
Fw
4g
Re
(b)
10 km
Legend
Lower Cenozoic
Cretaceous dolerite
Lower Cretaceous
Upper Jurassic
Lower Triassic–Middle Jurassic
Permian (Tempelfjorden Group)
Pennsylvanian–Permian (Gipsdalen Group)
Uppermost Devonian–Mississippian (Billefjorden Group)
Lower–lowermost Upper Devonian
Precambrian basement
Brittle faults
Thrusts
Folds
Coastline

Figure 1: (a) Topographic–bathymetric map around Spitsbergen modified after Jakobsson et al. (2012). Abbreviations: Ad: Adriabukta; Bi: Billefjorden; Bk: Bockfjorden; Bo: Blomstrandhalvøya; Br: Brøggerhalvøya; Fi: Fiskeknatten; Ha: Haitana; Hr: Hornsund; Is: Isfjorden; Kg: Kongsfjorden; Kr: Krosspynten; Ky: Krylen; Mi: Midterhuken; Pk: Påskefjellet; Pr: Pretender Mountain; Ra: Raudfjorden; Re: Reindalspasset; Rø: Røkensåta; Ss: Sassenfjorden; SJ: St-Jonsfjorden; Tp: Tempelfjorden; Tr: Triungen; (b) Geological map modified from svalbardkartet.npolar.no showing the main tectono-stratigraphic units and structures in the study area in central Spitsbergen. Abbreviations: AA: Atomfjella Antiform; Af: Adolfbukta; An: Anservika; BF: Balliolbreen Fault; BL: Bünsow Land;Bn: Bolen; BRF: Blåvatnet Reverse Fault; Fw: Flowerdalen; Gh: Gipshuken; Ki: Kilen; LMT: lower Munidalen thrust; Ly: Lykta; Lø: Løvehovden–Hultberget; Mn: Munindalen; Mu: Mumien; Od: Odellfjellet; OF: Odelfjellet Fault; Py: Pyramiden; Re: Reindalspasset; Rö: Reuterskiöldfjellet; Rs: Robertsonbreen; RT: Robertsonbreen thrust; Se: Sentinelfjellet; Sk: Storskarvet; Sæ: Sætherfjellet; TGFZ: Triungen–Grønhorgdalen Fault Zone; To: Torfjellet; Tr: Triungen; Tå: Tåkefjellet; UMT: upper Munidalen thrust; Yg: Yggdrasilkampen.

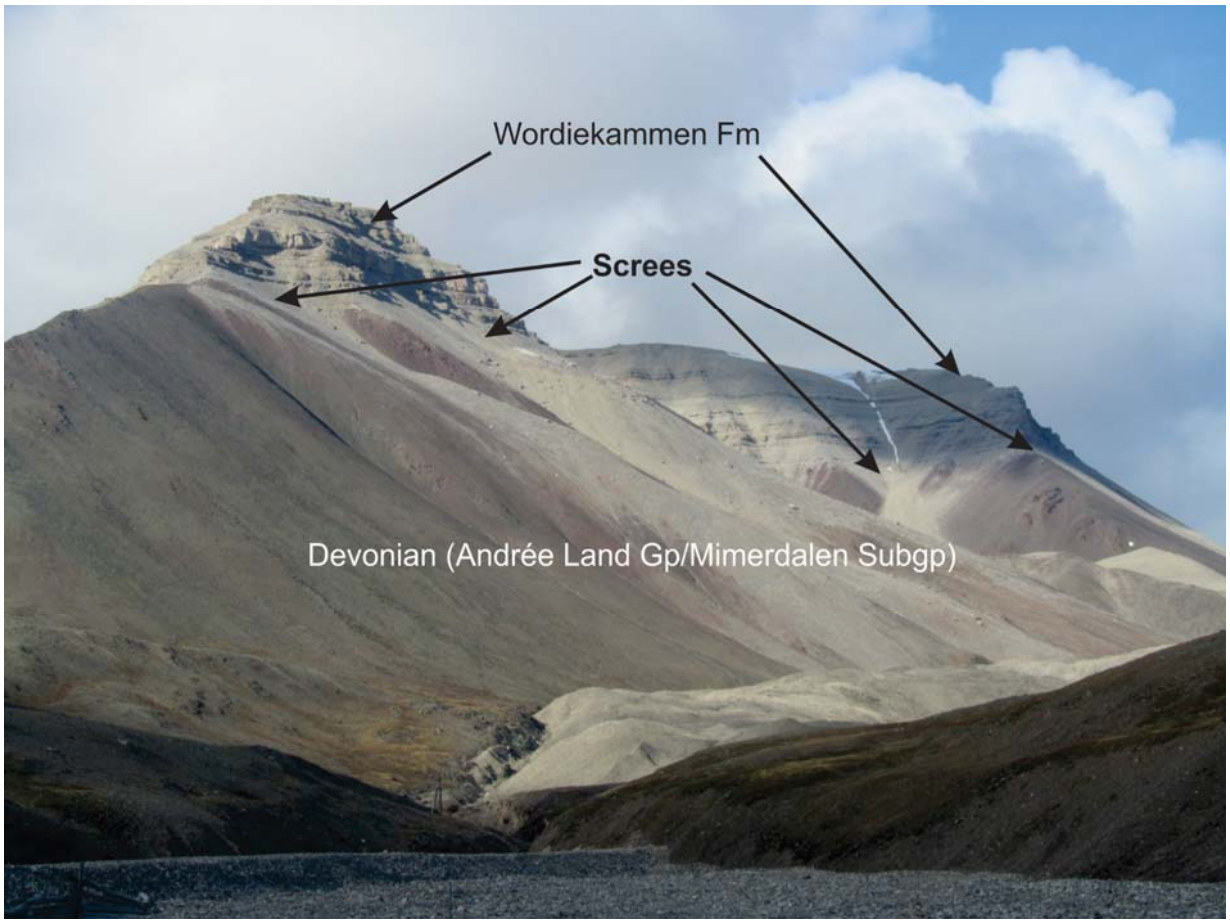


Figure 2: Field photograph showing the pervasive presence of screes and loose material along the boundary between rocks of the Andrée Land Group/Mimerdalen Subgroup and overlying strata of the Wordiekammen Formation, and the poorly preserved and mostly loose outcrops of rocks of the Andrée Land Group/Mimerdalen Subgroup in southern Reuterskiöldfjellet, in Dickson Land. Photo: Jean-Baptiste Koehl.

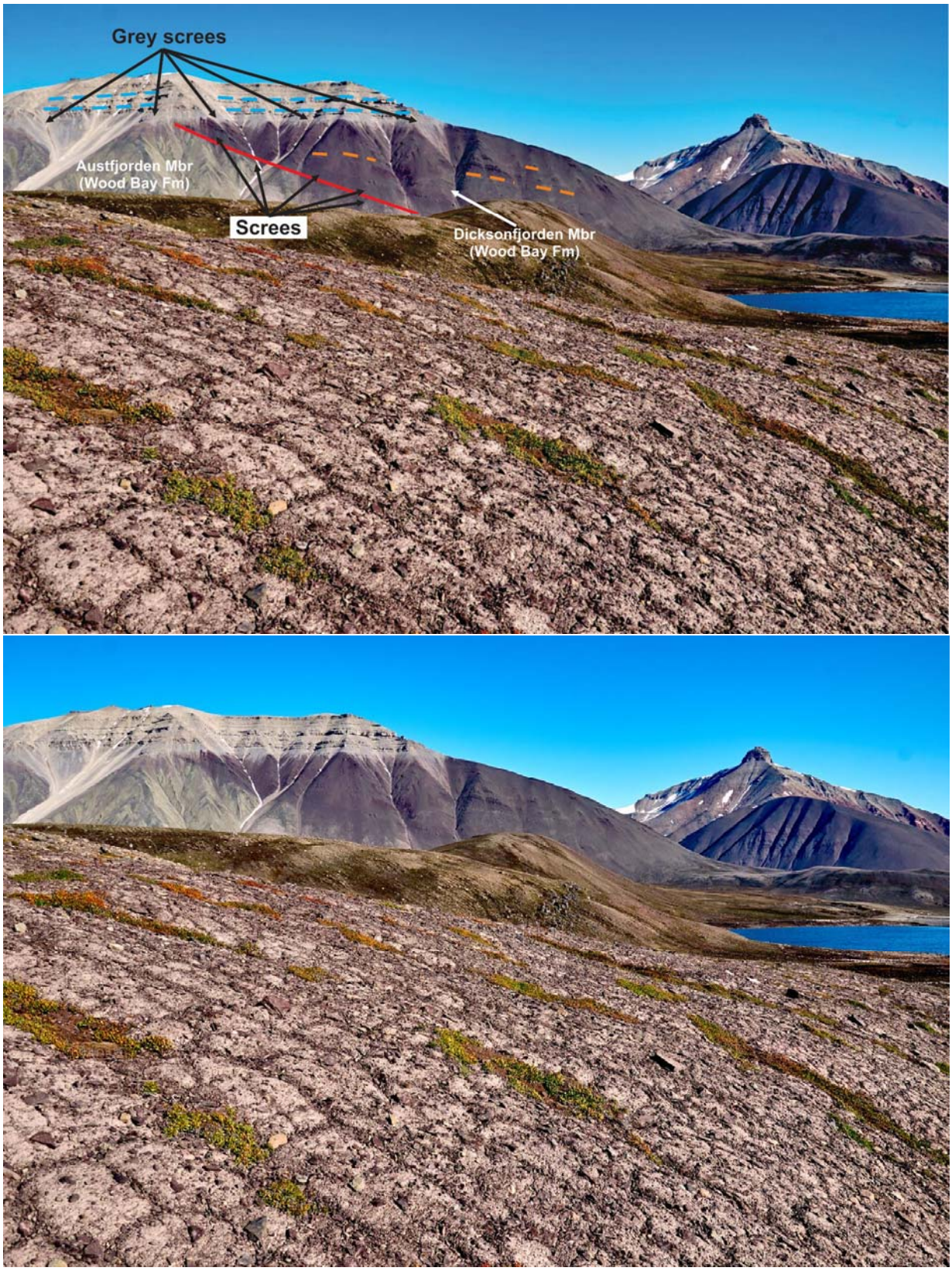

Grey screes
Austfjorden Mbr
(Wood Bay Fm)
Screes
Dicksonfjorden Mbr
(Wood Bay Fm)

Figure 3: (a) Interpreted and (b) uninterpreted field photograph showing the poor quality of outcrop transects of gently east dipping (tilted?) Lower Devonian rocks of poorly deformed red siltstones of the Dicksonfjorden Member and green sandstones of the Austfjorden Member of the Wood Bay Formation (dashed orange lines) unconformably overlain by flat-lying strata of the Wordiekammen Formation (dashed blue lines) in Reuterskiöldfjellet. The presence of abundant grey screes (from the Wordiekammen Formation) and the poorly preserved character of Lower Devonian outcrops (mostly consisting of loose material and bedding surface only possible to identify in a few places) makes it difficult to assess the nature of the unconformity (tectonized or non-tectonized?) between Lower Devonian and uppermost Pennsylvanian–lowermost Permian rocks and the nature of the boundary between the Austfjorden and Dicksonfjorden members of the Wood Bay Formation (interpreted as the upper Munindalen thrust by Piepjohn et al., 1997a and Michaelsen, 1998, her figure 53; plain red line). The gently east-dipping and poorly deformed character of Lower Devonian rocks in the area may be the product of Devonian extensional faulting (e.g., tilted along a low-angle late–post-Caledonian detachment/normal fault; e.g., Chorowicz, 1992; Friend et al., 1997, their figure 12b; McCann, 2000). View is towards the north. Photo: Reinhard Feisel.

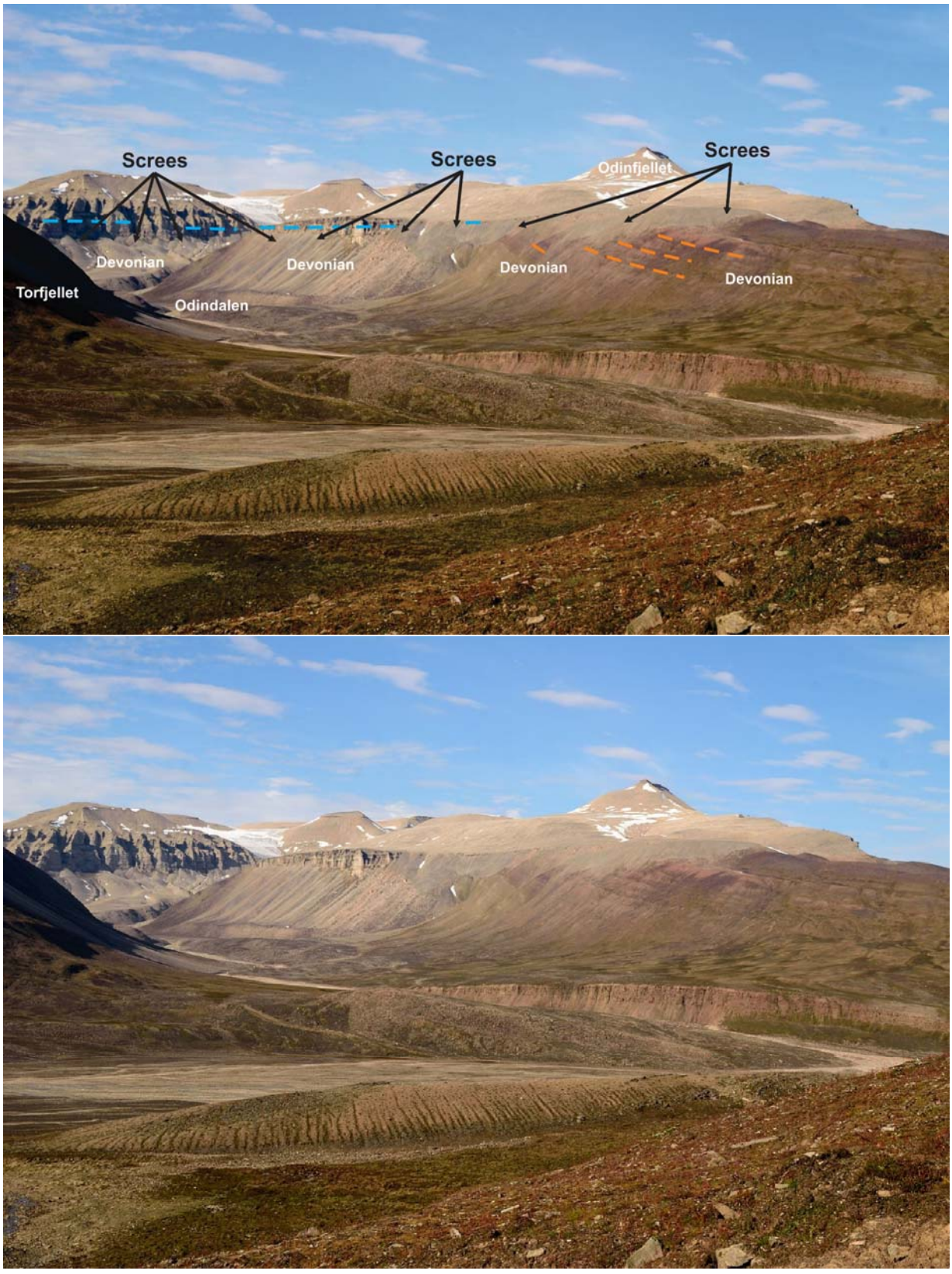
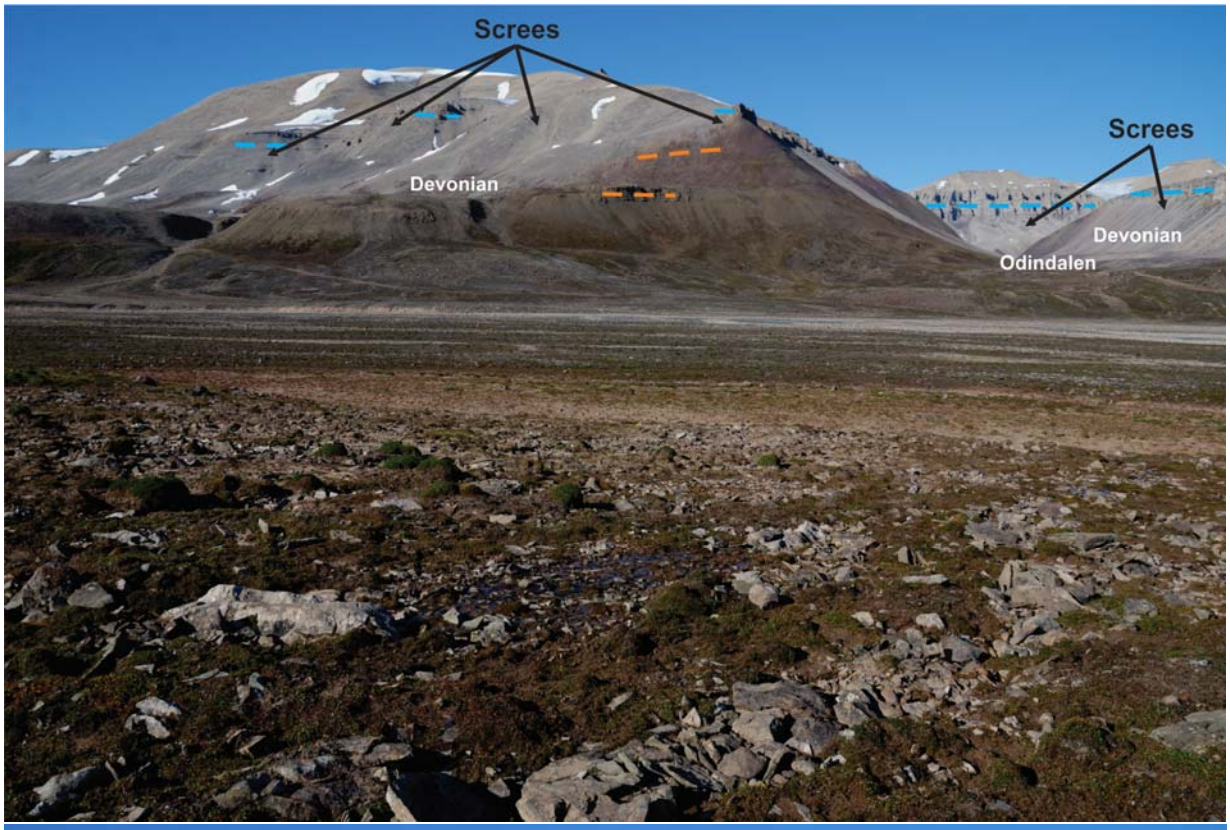

Screes
Screes
Screes
Odinfjellet
Devonian
Devonian
Devonian
Devonian
Torfjellet
Odindalen

Figure 4: (a) Interpreted and (b) uninterpreted field photograph showing the poor quality of outcrop transects of gently dipping (tilted?) Lower–lowermost Upper Devonian rocks of the Wood Bay Formation and Mimerdalen Subgroup (dashed orange lines) unconformably overlain by flat-lying strata of the Wordiekammen Formation (dashed blue lines) in Mimerdalen. The presence of abundant grey screes (from the Wordiekammen Formation) and the poorly preserved character of Lower–lowermost Upper Devonian outcrops (mostly consisting of loose material and bedding surface only possible to identify in a few places) makes it difficult to assess the nature of the unconformity (tectonized or non-tectonized?) almost everywhere in this area. The gently east-dipping and poorly deformed character of Lower–lowermost Upper Devonian rocks in the area may be related to Devonian extensional faulting (e.g., tilted along a low-angle late–post-Caledonian detachment/normal fault; e.g., Chorowicz, 1992; Friend et al., 1997, their figure 12b; McCann, 2000). View is towards the northwest. Photo: Reinhard Feisel.


Screens
Devonian
Screens
Devonian
Odindalen

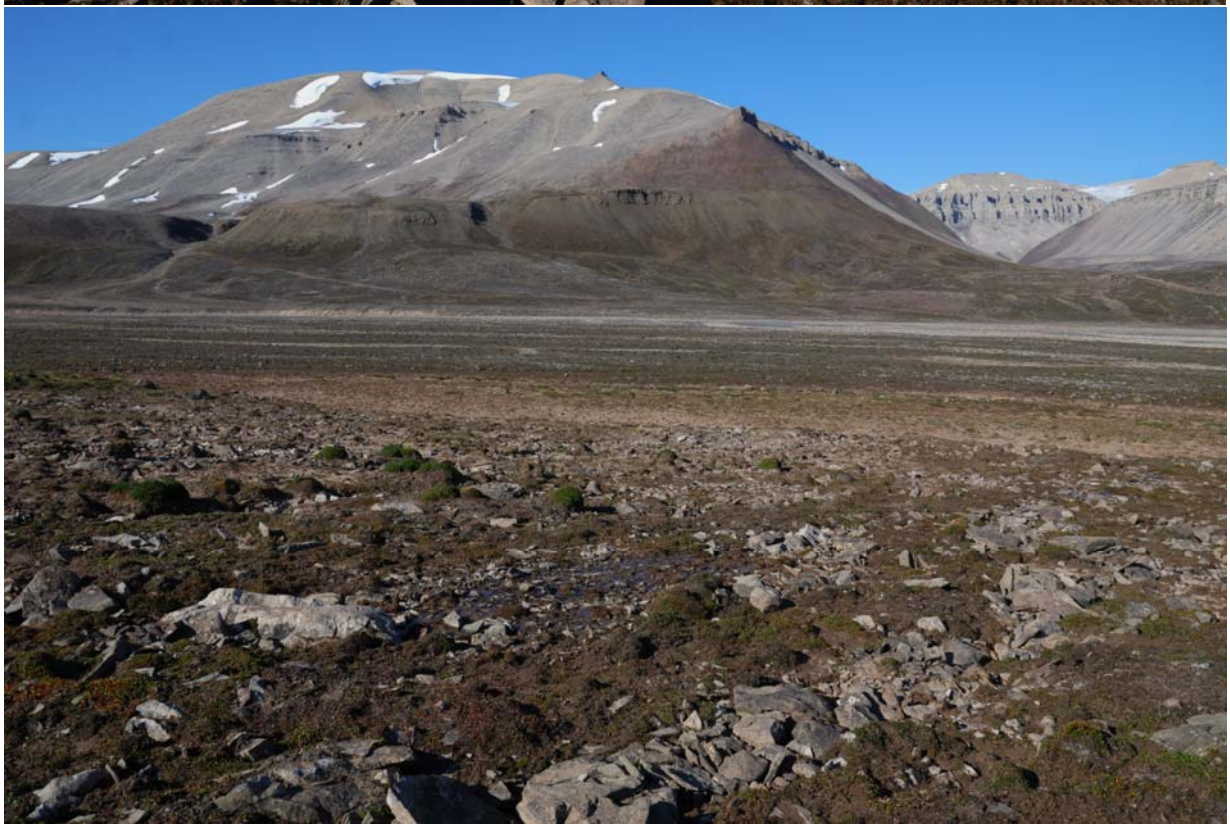


Figure 5: (a) Interpreted and (b) uninterpreted field photograph showing the poor quality of outcrop transects of gently dipping, poorly deformed (sub-horizontal bedding surfaces), Lower–lowermost Upper Devonian rocks of the Wood Bay Formation and Mimerdalen Subgroup (dashed orange lines) unconformably overlain by flat-lying strata of the uppermost Pennsylvanian–lowermost Permian Wordiekammen Formation (dashed blue lines) in Mimerdalen. Note the presence of abundant grey screes from the Wordiekammen Formation masking the unconformity between gently dipping Lower–lowermost Upper Devonian and uppermost Pennsylvanian–lowermost Permian strata. View is towards the west. Photo: Reinhard Feisel.

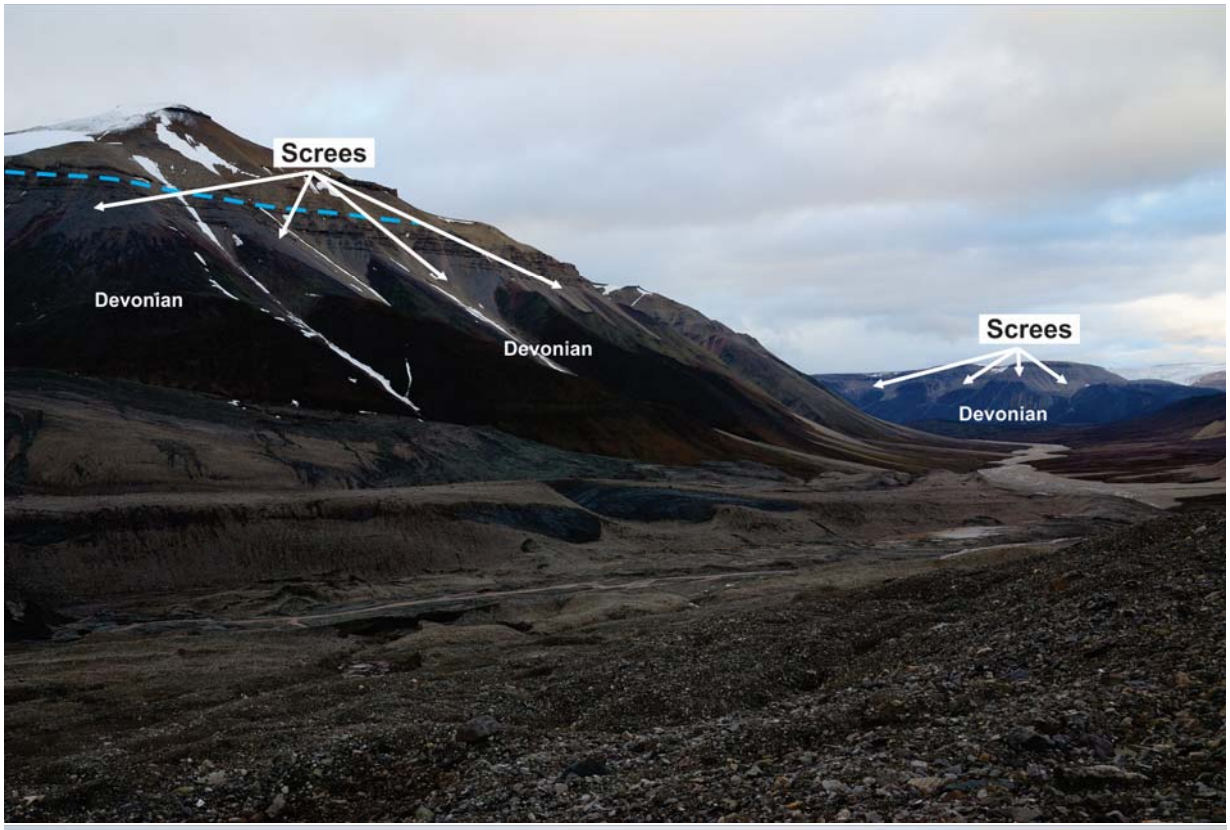

Screes
Devonian
Devonian
Screes
Devonian

Figure 6: (a) Interpreted and (b) uninterpreted field photograph showing the poor quality of outcrop transects of Lower–lowermost Upper Devonian rocks of the Wood Bay Formation and Mimerdalen Subgroup unconformably overlain by flat-lying strata of the uppermost Pennsylvanian–lowermost Permian Wordiekammen Formation (dashed blue lines) in Reuterskiöldfjellet and Yggdrasilkampen. Note the presence of abundant grey screes from the Wordiekammen Formation masking the unconformity between Lower–lowermost Upper Devonian and uppermost Pennsylvanian–lowermost Permian strata. View is towards the southeast. Photo: Reinhard Feisel.

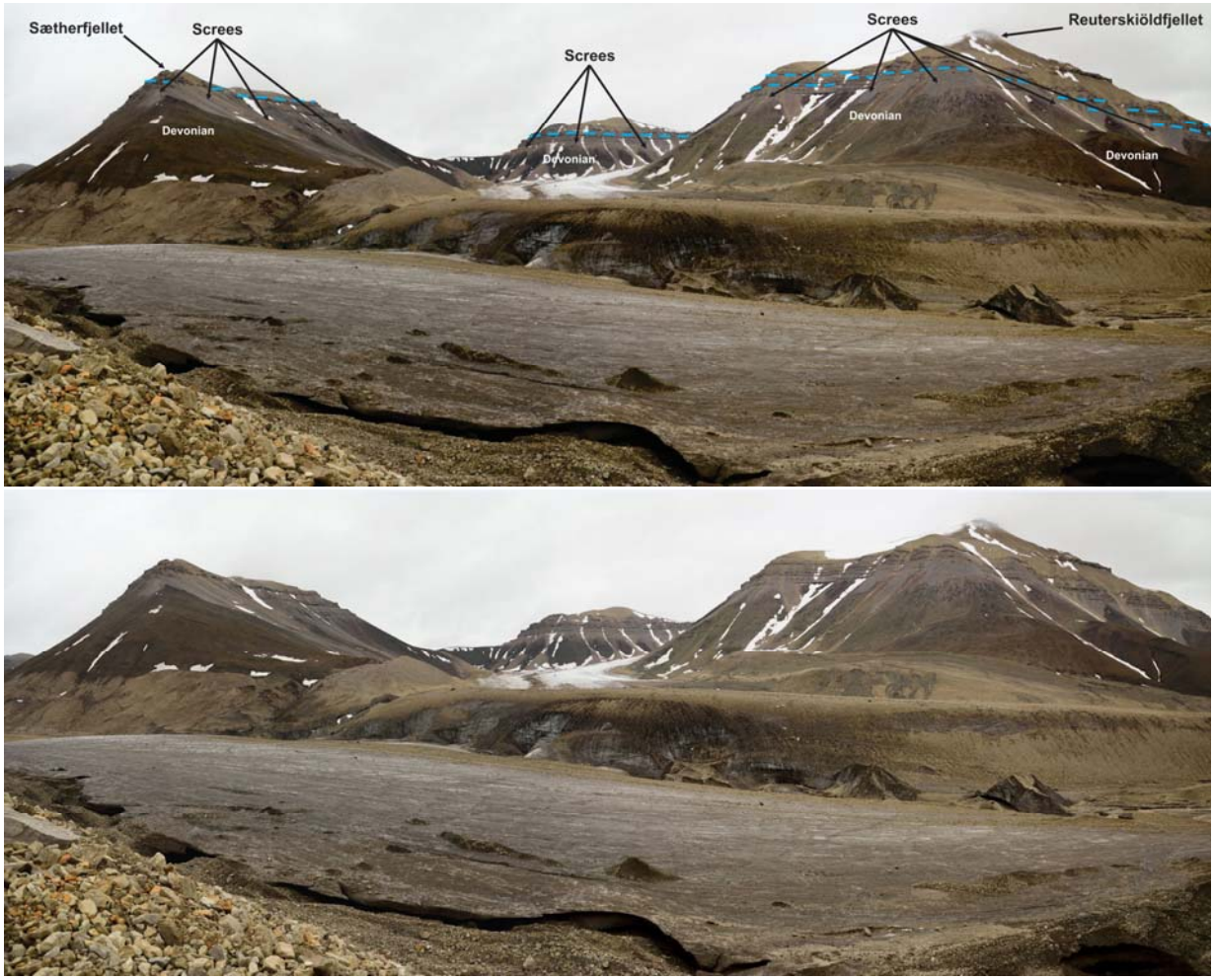


Figure 7: (a) Interpreted and (b) uninterpreted field photograph showing the poor quality of outcrop transects of Lower–lowermost Upper Devonian rocks of the Wood Bay Formation and Mimerdalen Subgroup unconformably overlain by flat-lying strata of the uppermost Pennsylvanian–lowermost Permian Wordiekammen Formation (dashed blue lines) in Sætherfjellet and Reuterskiöldfjellet. Note the presence of abundant grey screes from the Wordiekammen Formation masking the unconformity between Lower–lowermost Upper Devonian and uppermost Pennsylvanian–lowermost Permian strata. View is towards the northeast. Photo: Reinhard Feisel.

Figure 8: (a) Interpreted and (b) uninterpreted field photograph showing the poor quality of outcrop transects of Lower–lowermost Upper Devonian rocks of the Wood Bay Formation and Mimerdalen Subgroup unconformably overlain by flat-lying strata of the uppermost Pennsylvanian–lowermost Permian Wordiekammen Formation (dashed blue lines) in Munindalen. Note the presence of abundant grey screes from the Wordiekammen Formation masking the unconformity between Lower–lowermost

Upper Devonian and uppermost Pennsylvanian–lowermost Permian strata pretty much everywhere in this area. View is towards the north. Photo: Reinhard Feisel.

Figure 9: (a) Interpreted and (b) uninterpreted field photograph showing the poor quality of outcrop transects of Lower–lowermost Upper Devonian rocks of the Wood Bay Formation and Mimerdalen Subgroup unconformably overlain by flat-lying strata of the uppermost Pennsylvanian–lowermost Permian Wordiekammen Formation (dashed blue lines) in Storskarvet, Kilen and Sætherfjillet, in Munindalen. Note the presence of abundant grey screes from the Wordiekammen Formation masking the unconformity between Lower–lowermost Upper Devonian and uppermost Pennsylvanian–lowermost Permian strata. View is towards the north. Photo: Reinhard Feisel.

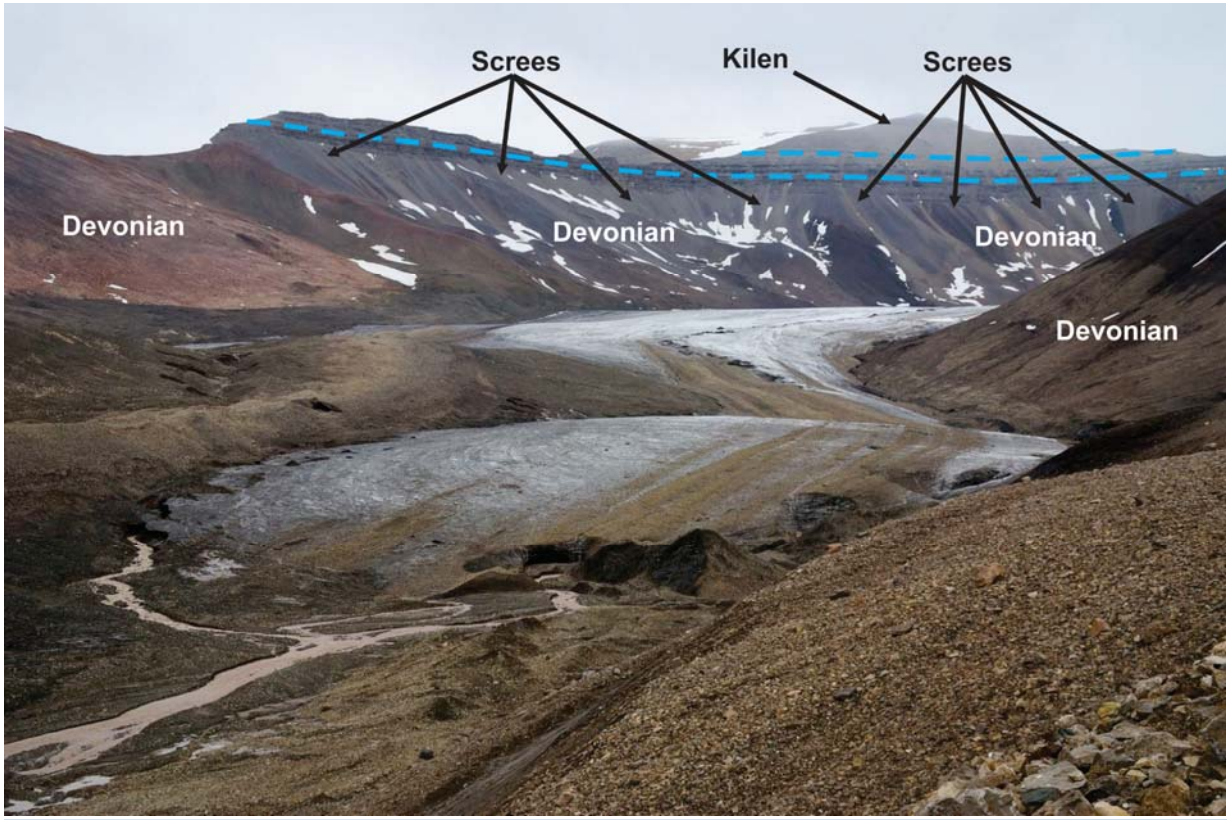

Screes
Kilen
Screes
Devonian
Devonian
Devonian
Devonian

Figure 10: (a) Interpreted and (b) uninterpreted field photograph showing the poor quality of outcrop transects of Lower–lowermost Upper Devonian rocks of the Wood Bay Formation and Mimerdalen Subgroup unconformably overlain by flat-lying strata of the uppermost Pennsylvanian–lowermost Permian Wordiekammen Formation (dashed blue lines) in Kilen, in Munindalen. Note the presence of abundant grey screes from the Wordiekammen Formation masking the unconformity between Lower–lowermost Upper Devonian and uppermost Pennsylvanian–lowermost Permian strata. View is towards the north-northwest. Photo: Reinhard Feisel.


Screees
Screees
Screees
Screees
Screees
Devonian
Devonian
Devonian

Figure 11: (a) Interpreted and (b) uninterpreted zoom in the field photograph in Kilen. The outcrop transects of gently east-dipping (tilted?) Lower–lowermost Upper Devonian rocks of the Wood Bay Formation and Mimerdalen Subgroup (dashed orange lines) are mostly made up with loose material and unconformably overlain by flat-lying strata of the uppermost Pennsylvanian–lowermost Permian Wordiekammen Formation (dashed blue lines). Note the presence of abundant grey screes from the Wordiekammen Formation masking the unconformity between Lower–lowermost Upper Devonian and uppermost Pennsylvanian–lowermost Permian strata, making it difficult to study the nature of the unconformity (tectonized or non-tectonized?). The gently east-dipping and poorly deformed character of Lower–lowermost Upper Devonian rocks in the area below the unconformity may be related to Devonian extensional faulting (e.g., tilted along a low-angle late–post-Caledonian detachment; e.g., Chorowicz, 1992; Friend et al., 1997, their figure 12b; McCann, 2000). View is towards the north-north. Photo: Reinhard Feisel.

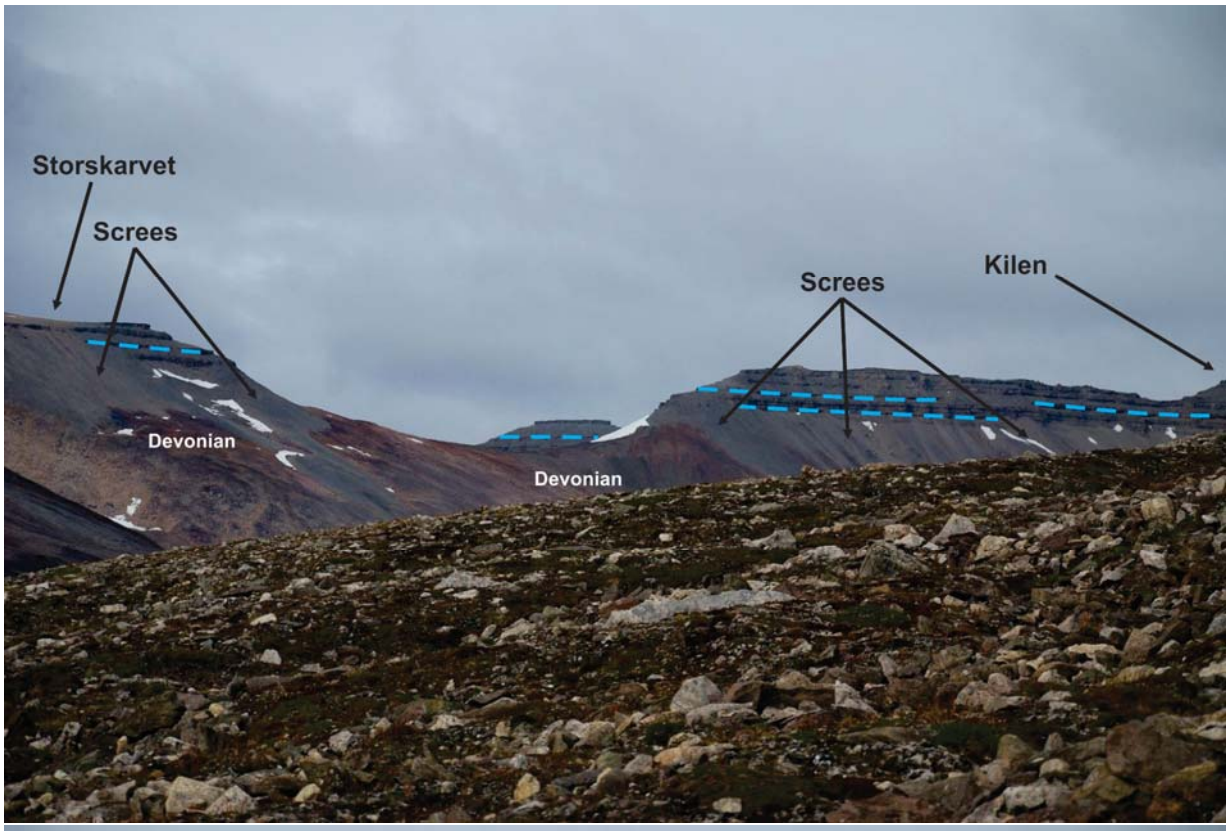

Storskarvet
Screes
Screes
Kilen
Devonian
Devonian

Figure 12: (a) Interpreted and (b) uninterpreted field photograph showing the poor quality of outcrop transects of Lower–lowermost Upper Devonian rocks of the Wood Bay Formation and Mimerdalen Subgroup unconformably overlain by flat-lying strata of the uppermost Pennsylvanian–lowermost Permian Wordiekammen Formation (dashed blue lines) in Kilen and Storskarvet, in Munindalen. Note the presence of abundant grey screes from the Wordiekammen Formation masking the unconformity between Lower–lowermost Upper Devonian and uppermost Pennsylvanian–lowermost Permian strata. View is towards the west. Photo: Reinhard Feisel.

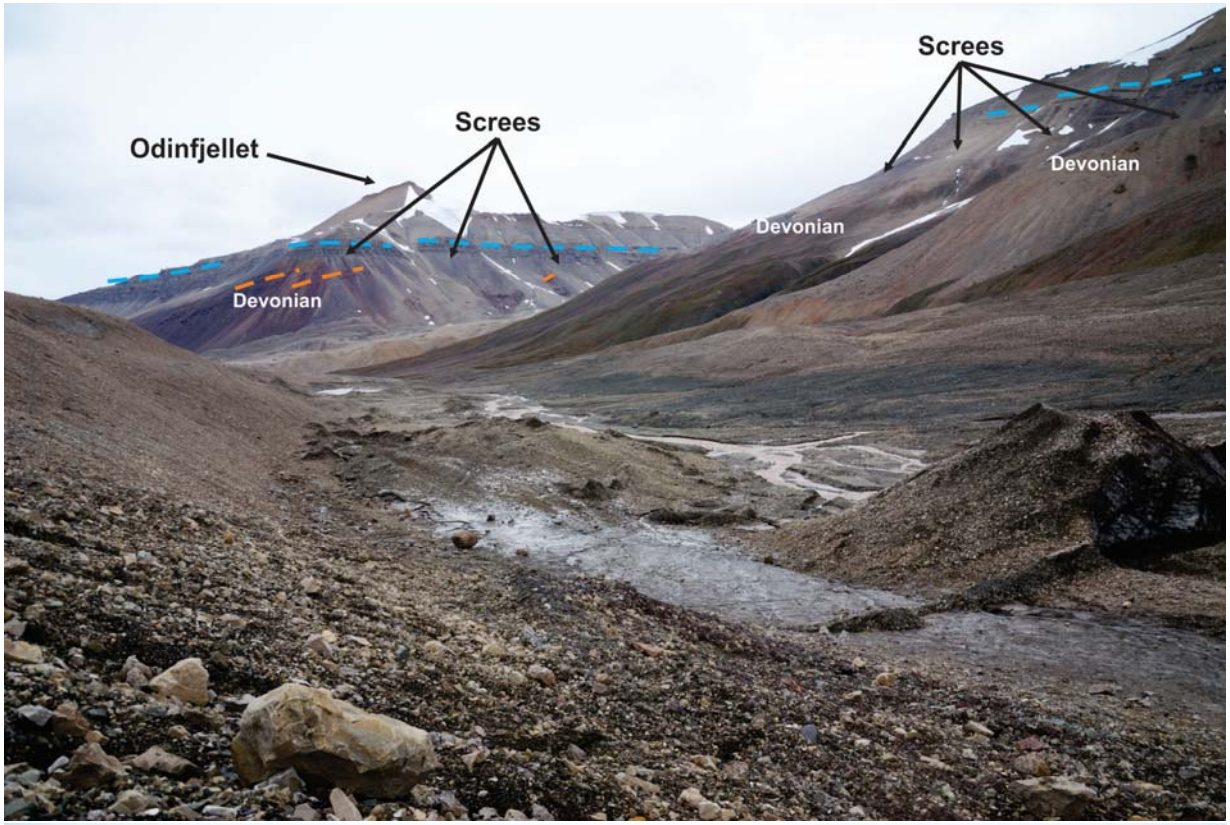

Screens
Odinfjellet
Screens
Devonian
Devonian
Devonian

Figure 13: (a) Interpreted and (b) uninterpreted field photograph showing the poor quality of outcrop transects of gently east-dipping (tilted?) Lower–lowermost Upper Devonian rocks of the Wood Bay Formation and Mimerdalen Subgroup (dashed orange lines) unconformably overlain by flat-lying strata of the uppermost Pennsylvanian–lowermost Permian Wordiekammen Formation (dashed blue lines) in Odinfjellet. Note the presence of abundant grey screes from the Wordiekammen Formation masking the unconformity between Lower–lowermost Upper Devonian and uppermost Pennsylvanian–lowermost Permian strata. The gently east-dipping and poorly deformed character of Lower–lowermost Upper Devonian rocks in the area may be related to Devonian extensional faulting (e.g., tilted along a low-angle late–post-Caledonian detachment; e.g., ; e.g., Chorowicz, 1992; Friend et al., 1997, their figure 12b; McCann, 2000). View is from Munindalen towards the south-southwest. Photo: Reinhard Feisel.

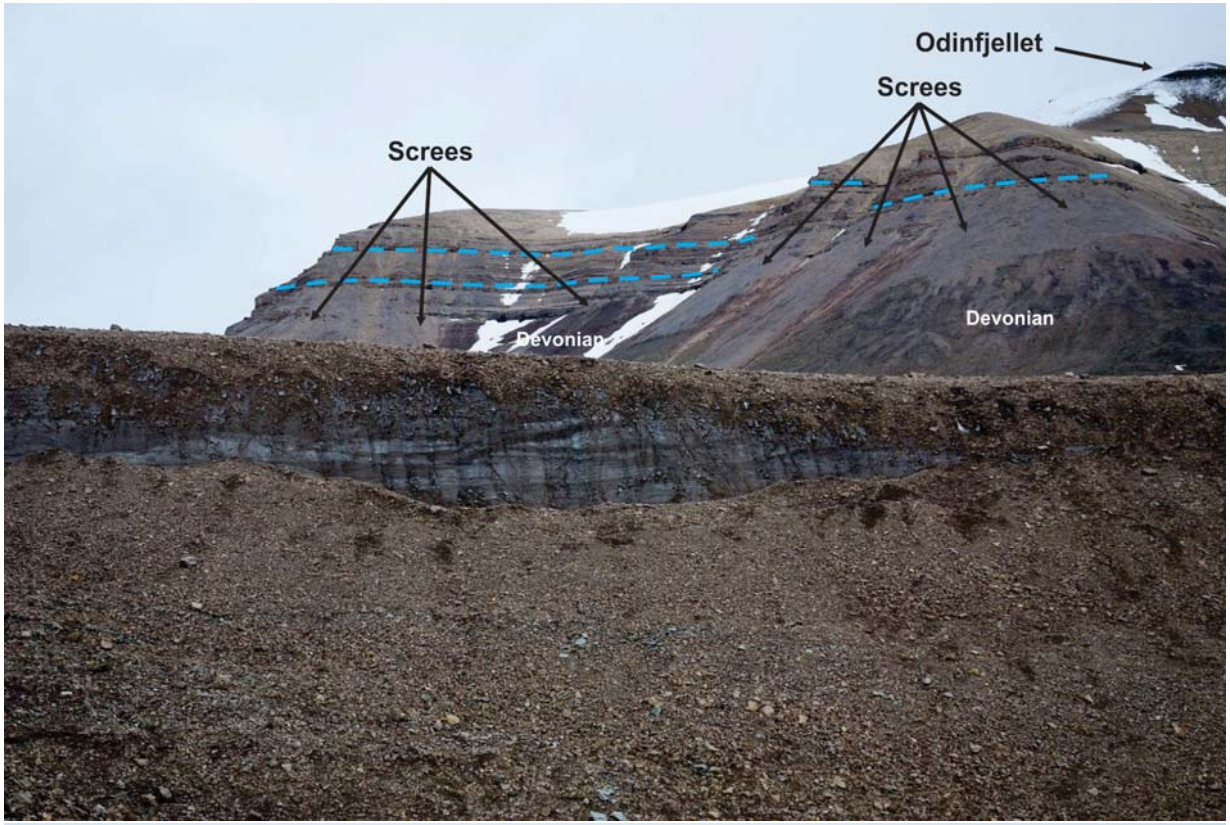

Odinfjellet
Screes
Screes
Devonian
Devonian

Figure 14: (a) Interpreted and (b) uninterpreted field photograph showing the poor quality of outcrop transects of Lower–lowermost Upper Devonian rocks of the Wood Bay Formation and Mimerdalen Subgroup unconformably overlain by flat-lying strata of the uppermost Pennsylvanian–lowermost Permian Wordiekammen Formation (dashed blue lines) in Odinfjellet. Note the presence of abundant grey screes from the Wordiekammen Formation masking the unconformity between Lower–lowermost Upper Devonian and uppermost Pennsylvanian–lowermost Permian strata. View is from Munindalen towards the south-southwest. Photo: Reinhard Feisel.

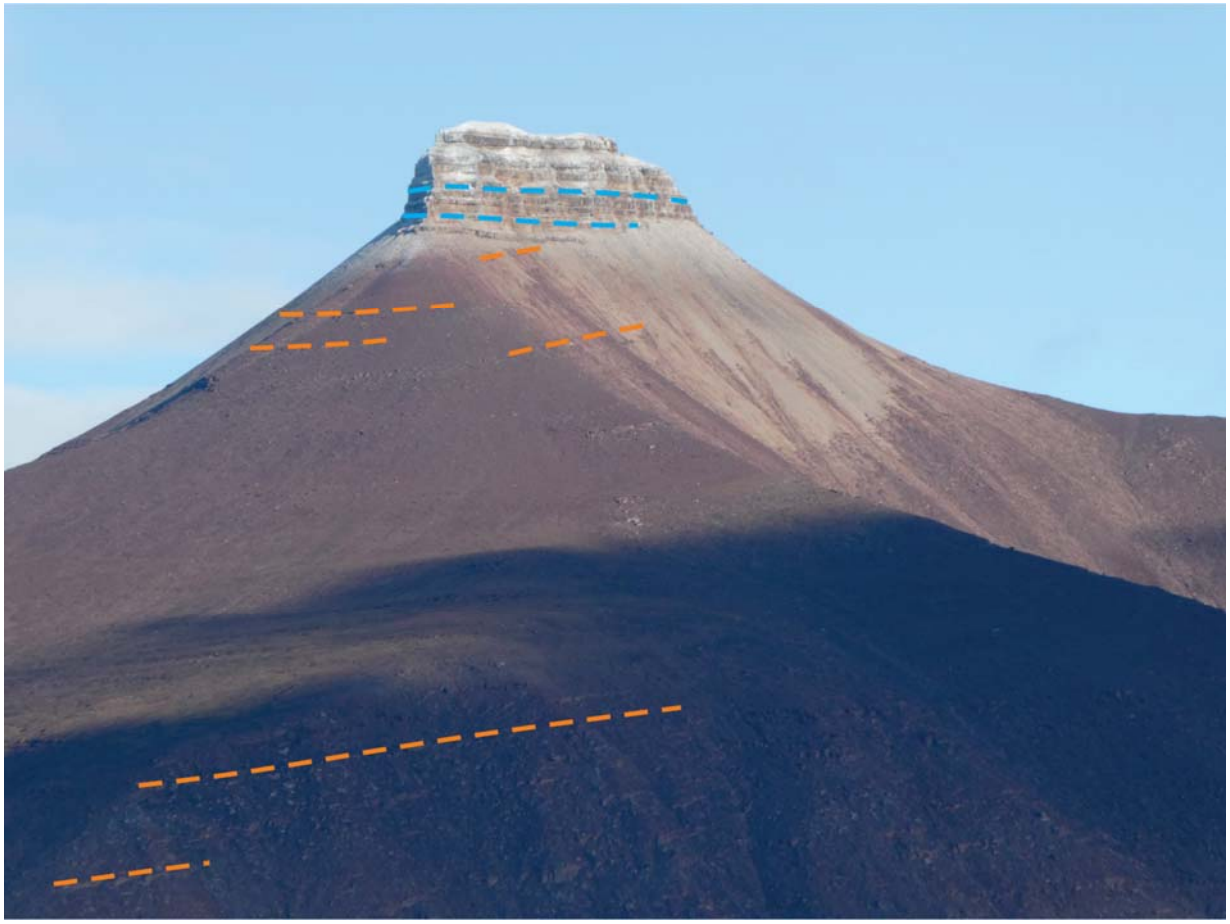


Figure 15: (a) Interpreted and (b) uninterpreted field photograph of the Lykta mountain in Dickson Land (c. five kilometers northwest of Triungen) showing gently dipping (tilted?) Lower Devonian strata of the Wood Bay Formation (dashed orange lines) unconformably overlain by flat-lying strata of the Wordiekammen Formation (dashed blue lines). The gently dipping and poorly deformed character of Lower Devonian rocks in the area may be the product of Devonian extensional faulting (e.g., tilted along a low-angle late–post-Caledonian detachment; e.g., Chorowicz, 1992; Friend et al., 1997, their figure 12b; McCann, 2000). View towards the north. Photo: Erik P. Johannessen.

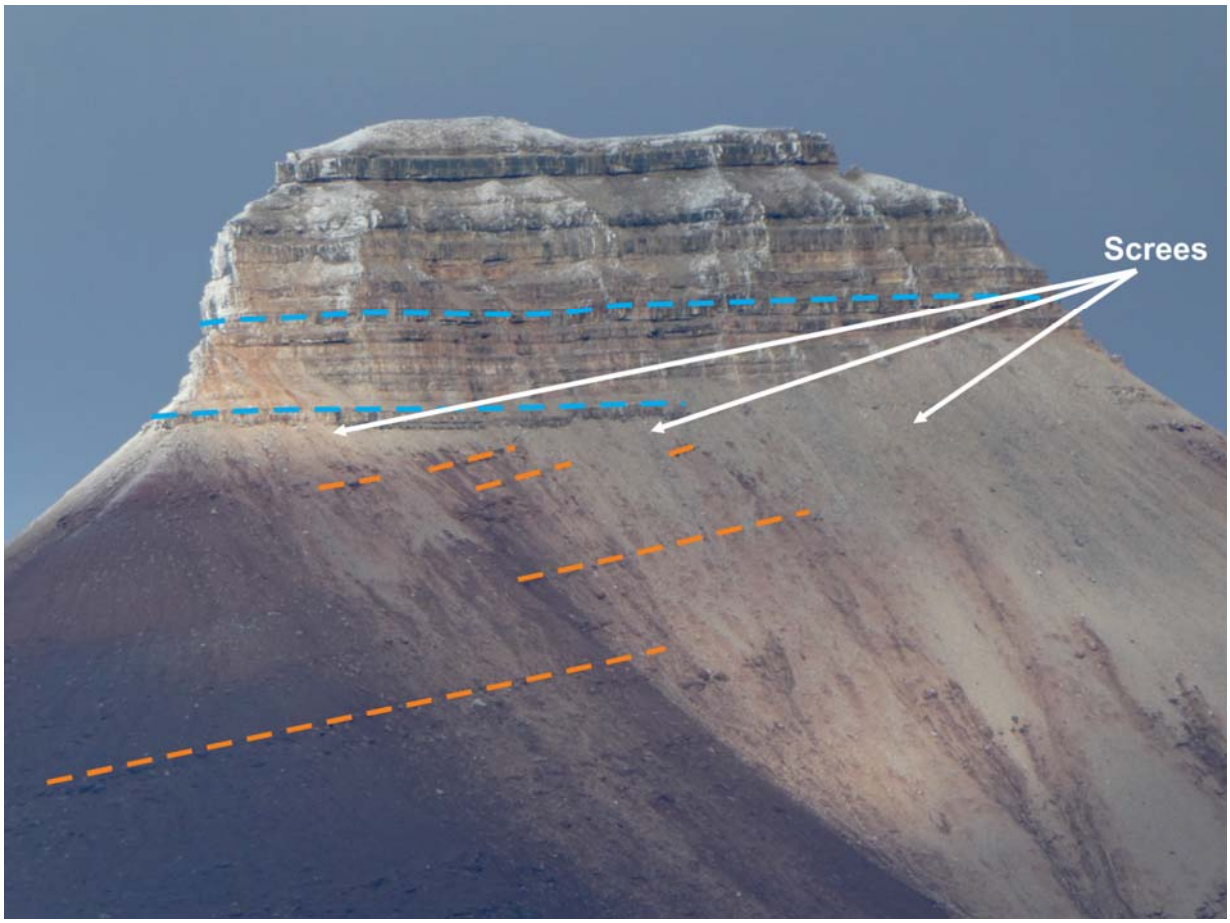

Screes

Figure 16: (a) Interpreted and (b) uninterpreted zoom in the top of the Lykta mountain in Dickson Land showing that the unconformity between gently west-dipping (tilted?), poorly deformed Lower Devonian strata of the Wood Bay Formation (dashed orange lines) and flat-lying strata of the Wordiekammen Formation (dashed blue lines) is covered by grey screes from the Wordiekammen Formation and, thus, its nature is not possible to directly observe (undeformed or tectonized unconformity?). View is towards the north. Photo: Erik P. Johannessen.

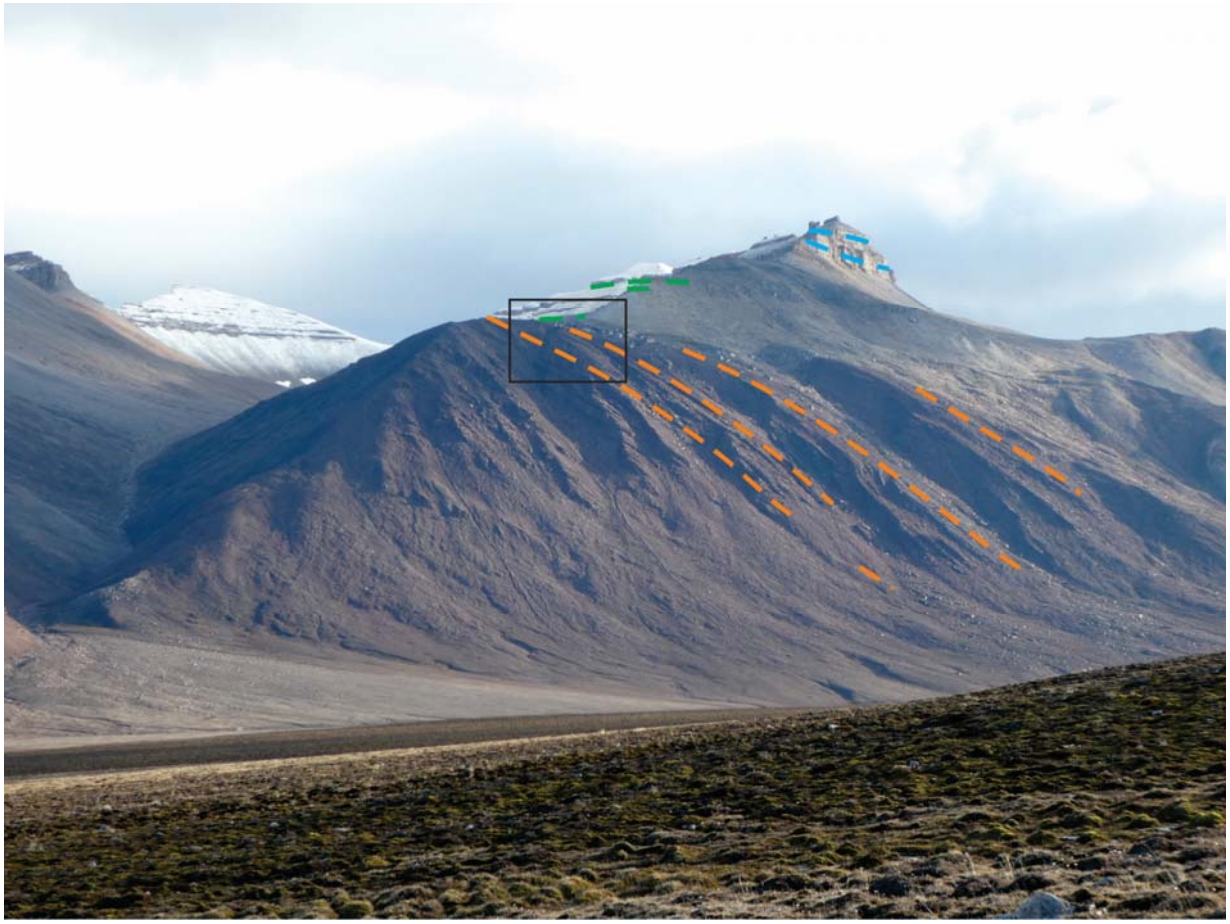


Figure 17: (a) Interpreted and (b) uninterpreted field photograph of the Triungen locality showing southwards-dipping (tilted?) Lower Devonian strata of the Wood Bay Formation (dashed orange lines) unconformably overlain by flat-lying strata of the Billefjorden Group (dashed green lines) and Wordiekammen Formation (dashed blue lines). The gently–moderately dipping and poorly deformed character of Lower Devonian rocks in the area may well be the product of Devonian extensional faulting (e.g., tilted along a low-angle late–post-Caledonian detachment/normal fault; e.g., Chorowicz, 1992; Friend et al., 1997, their figure 12b; McCann, 2000). View is towards the east. Photo: Erik P. Johannessen.

Figure 18: (a) Interpreted and (b) uninterpreted zoom in southwards-dipping (tilted?) Lower Devonian strata of the Wood Bay Formation (dashed orange lines) unconformably overlain by flat-lying strata of the Billefjorden Group (dashed green line) in Triungen (location shown as a black frame in Figure 17a). View is towards the east. Photo: Erik P. Johannessen.

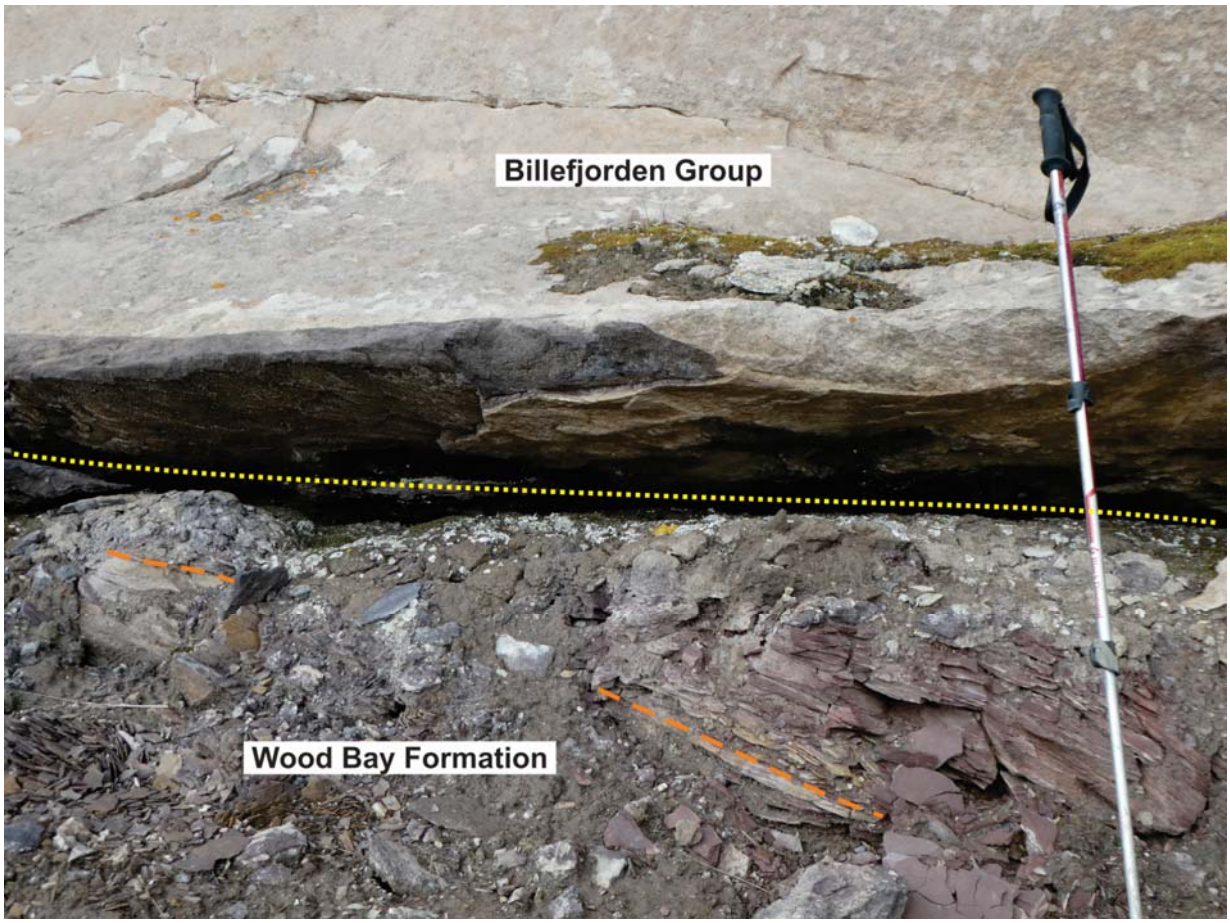

Billefjorden Group
Wood Bay Formation

Figure 19: (a) Interpreted and (b) uninterpreted field photograph of the angular stratigraphy unconformity (dotted yellow line) between gently-dipping (tilted?) Lower Devonian strata of the Wood Bay Formation (dashed orange lines) unconformably overlain by flat-lying strata of the Billefjorden Group in Triungen. Photo: Erik P. Johannessen.

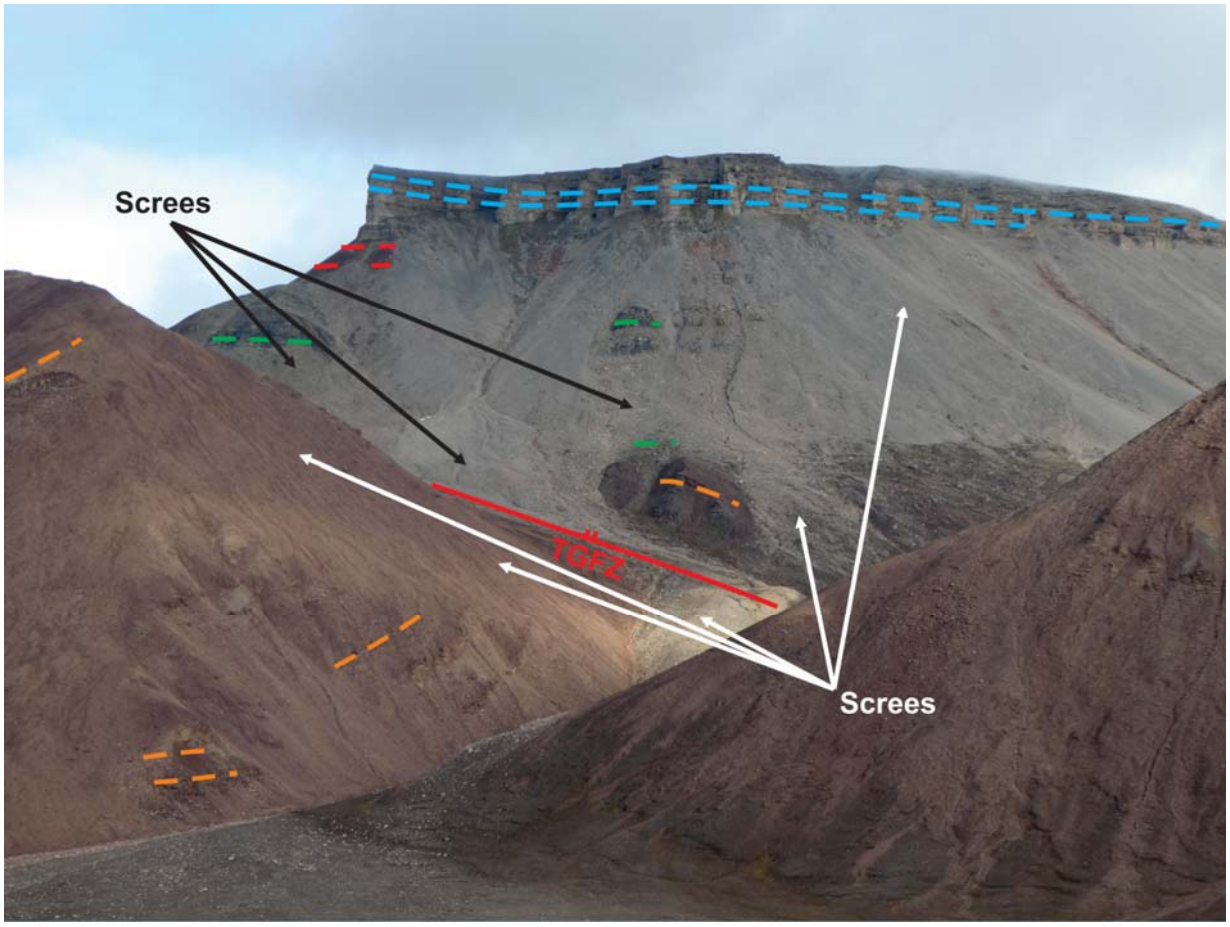

Screees
TGFZ
Screes

Figure 20: (a) Interpreted and (b) uninterpreted field photograph showing gently west-dipping strata of the Wood Bay Formation (dashed orange lines) overlain by flat-lying strata of the Billefjorden Group (dashed green lines), Hultberget Formation (dashed red line) and Wordiekammen Formation (dashed blue lines), and the probable trace of the Triugen–Grønhorgdalen Fault Zone (TGFZ; plain red line) in Triungen. The photograph shows that the trace of the TGFZ and most outcrops along the fault trace are covered by screes and loose material. View is towards the north-northeast. The gently dipping and poorly deformed character of Lower Devonian rocks in the area may well be the product of Devonian extensional faulting (e.g., tilted along a low-angle late–post-Caledonian detachment/normal fault; e.g., Chorowicz, 1992; McCann, 2000). Photo: Erik P. Johannessen.

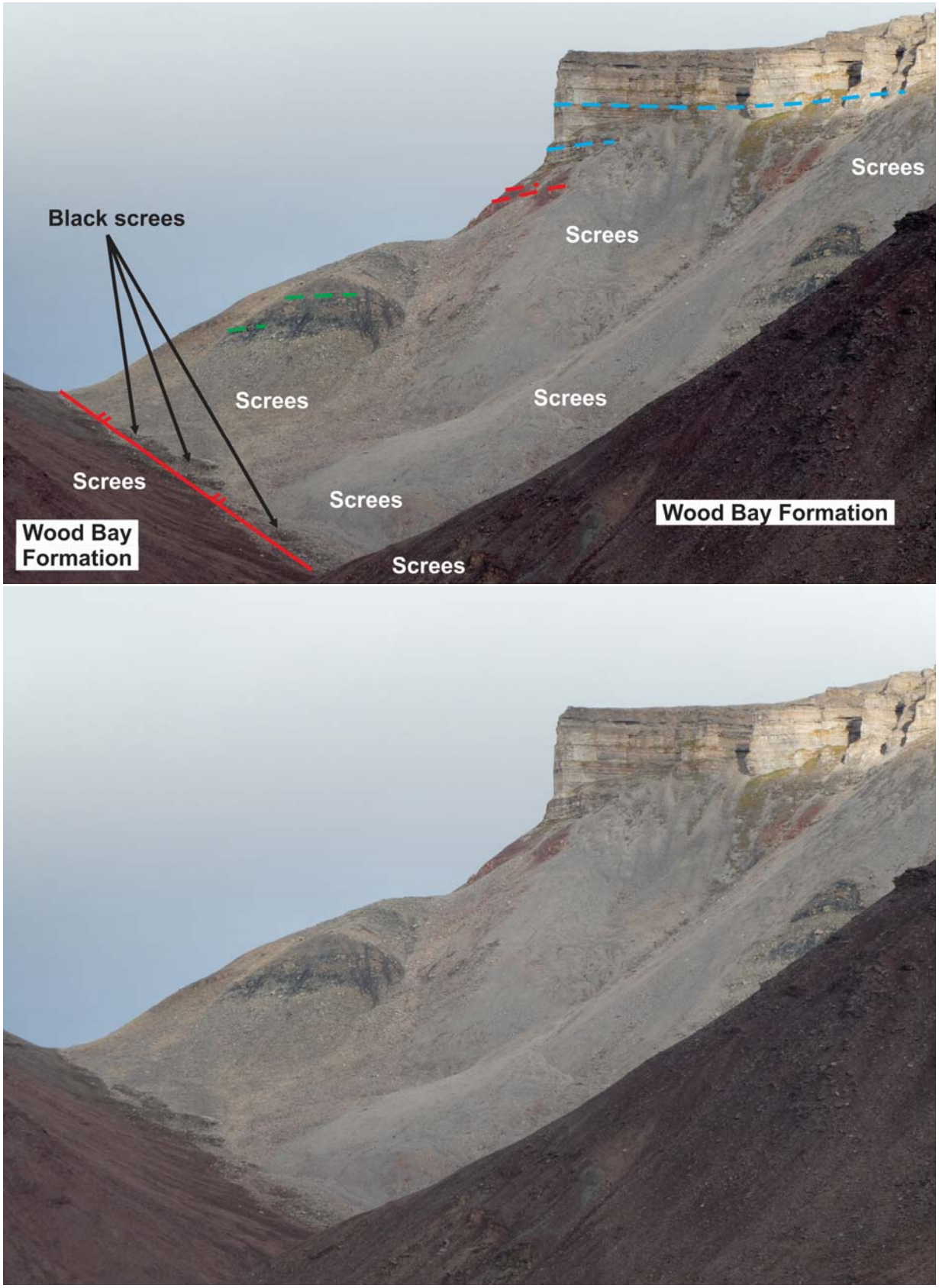

Black screees
Screes
Screes
Screes
Screes
Screes
Screes
Screes
Wood Bay Formation
Wood Bay Formation

Figure 21: (a) Interpreted and (b) uninterpreted field photograph showing the presence of abundant black screes (possibly from coals of the Billefjorden Group) and loose material along the trace of the Triungen–Grønhorgdalen Fault Zone (plain red line) between gently west-dipping strata of the Wood Bay Formation (dashed orange lines) and flat-lying strata of the Billefjorden Group (dashed green lines), Hultberget Formation (dashed red line) and Wordiekammen Formation (dashed blue lines) in Triungen. View is towards the north. Photo: Erik P. Johannessen.

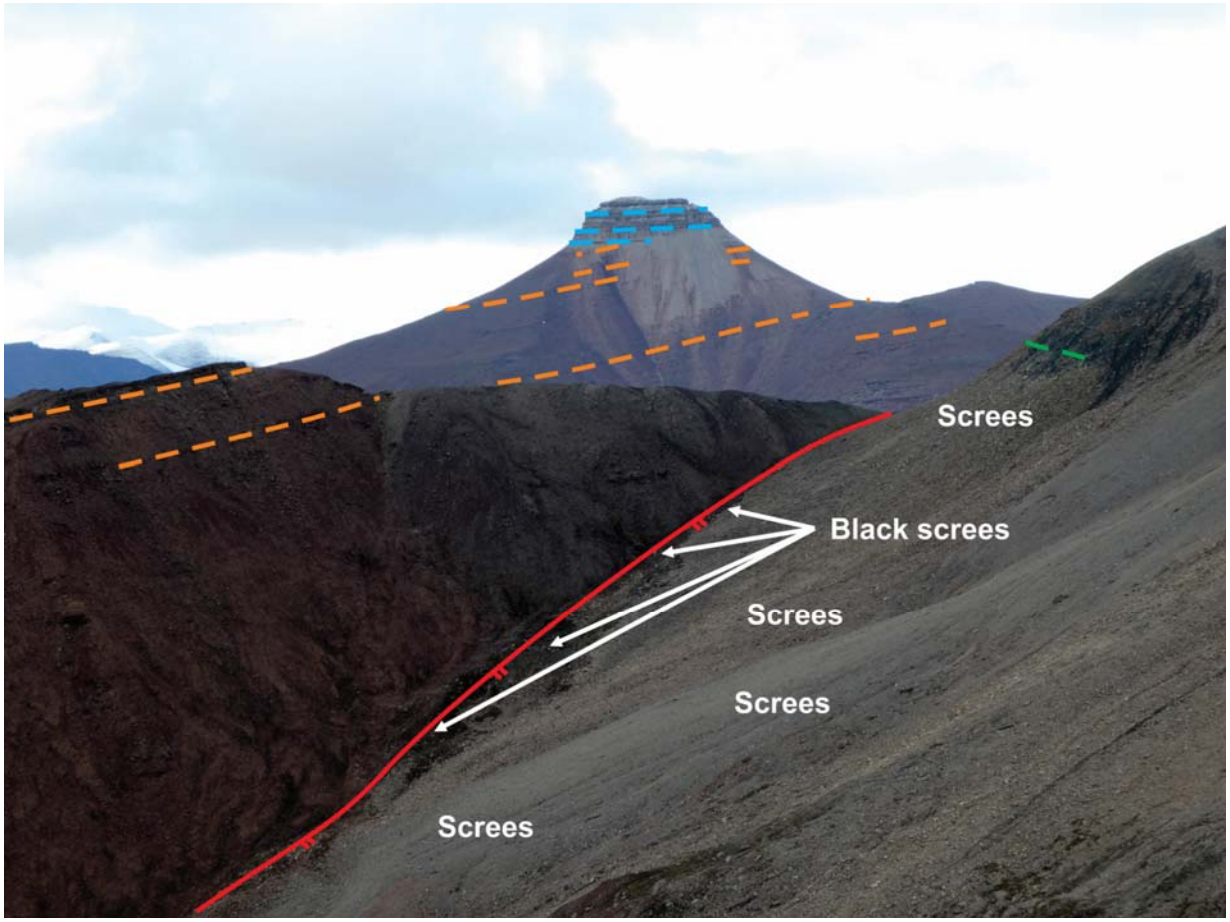

Screes
Black screes
Screes
Screes
Screes

Figure 22: Same as Figure 21. View is towards the northwest (Lykta mountain in the background). The gently dipping and poorly deformed character of Lower Devonian rocks in the area may well be the product of Devonian extensional faulting (e.g., tilted along a low-angle late–post-Caledonian detachment; e.g., Chorowicz, 1992; Friend et al., 1997, their figure 12b; McCann, 2000). Photo: Erik P. Johannessen.

Figure 23: (a) Interpreted and (b) uninterpreted field photograph showing gently dipping to flat-lying strata of the Wood Bay Formation (dashed orange lines) unconformably overlain by flat-lying strata of the Wordiekammen Formation (dashed blue lines) along the northern flank of Tåkefjellet (c. five kilometers south of Triungen) in Dickson Land. The gently dipping (tilted?) and poorly deformed character of Lower Devonian rocks in the area may well be the product of Devonian extensional faulting (e.g., tilted along a low-angle late–post-Caledonian detachment; e.g., Chorowicz, 1992; Friend et al., 1997, their figure 12b; McCann, 2000). View is towards the southeast. Photo: Erik P. Johannessen.

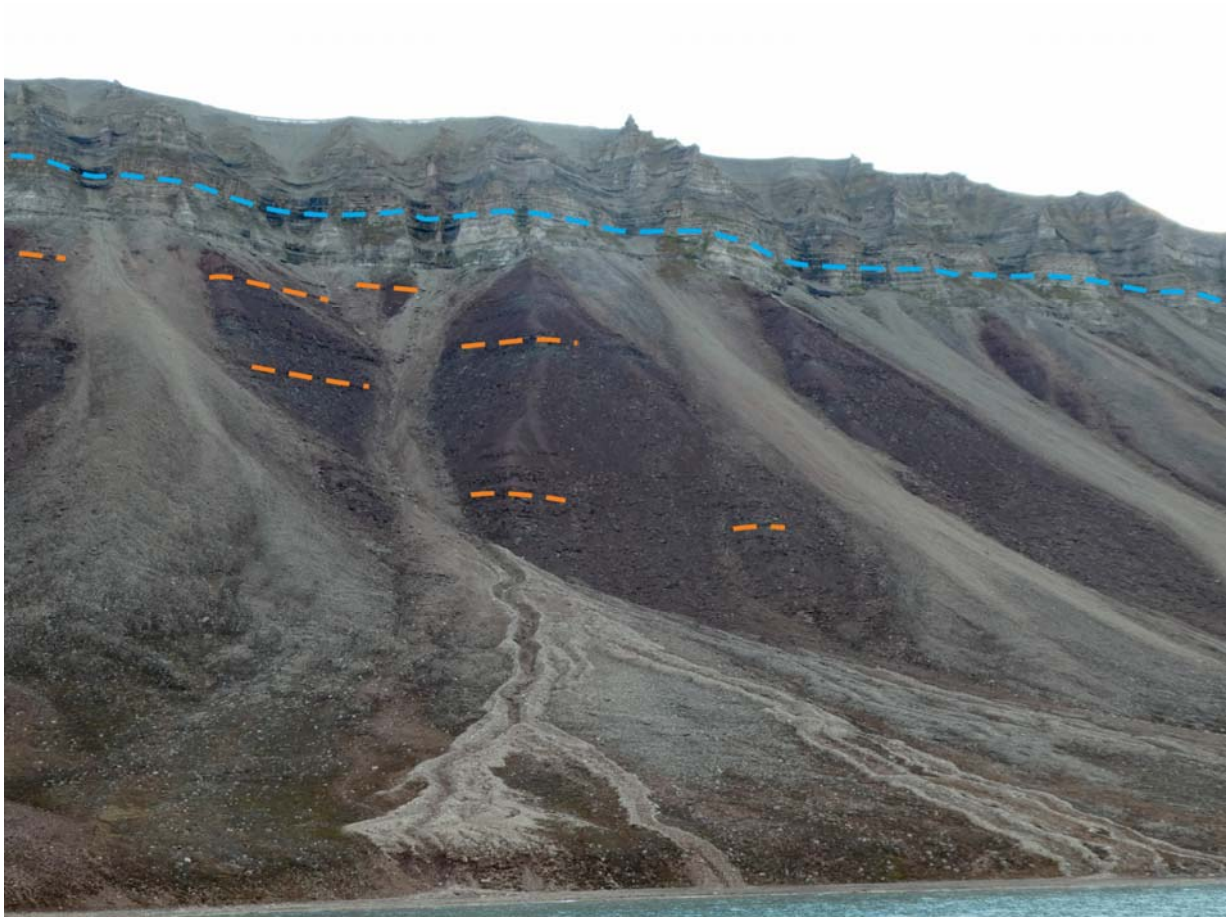


Figure 24: (a) Interpreted and (b) uninterpreted field photograph showing flat-lying to gently southwards-dipping (tilted?) and poorly deformed (sub-horizontal bedding surfaces) strata of the Wood Bay Formation (dashed orange lines) unconformably overlain by strata of the Wordiekammen Formation (dashed blue lines) along the western flank of Tåkefjellet (c. five kilometers southwest of Triungen) in Dickson Land. View is towards the east. Photo: Erik P. Johannessen.

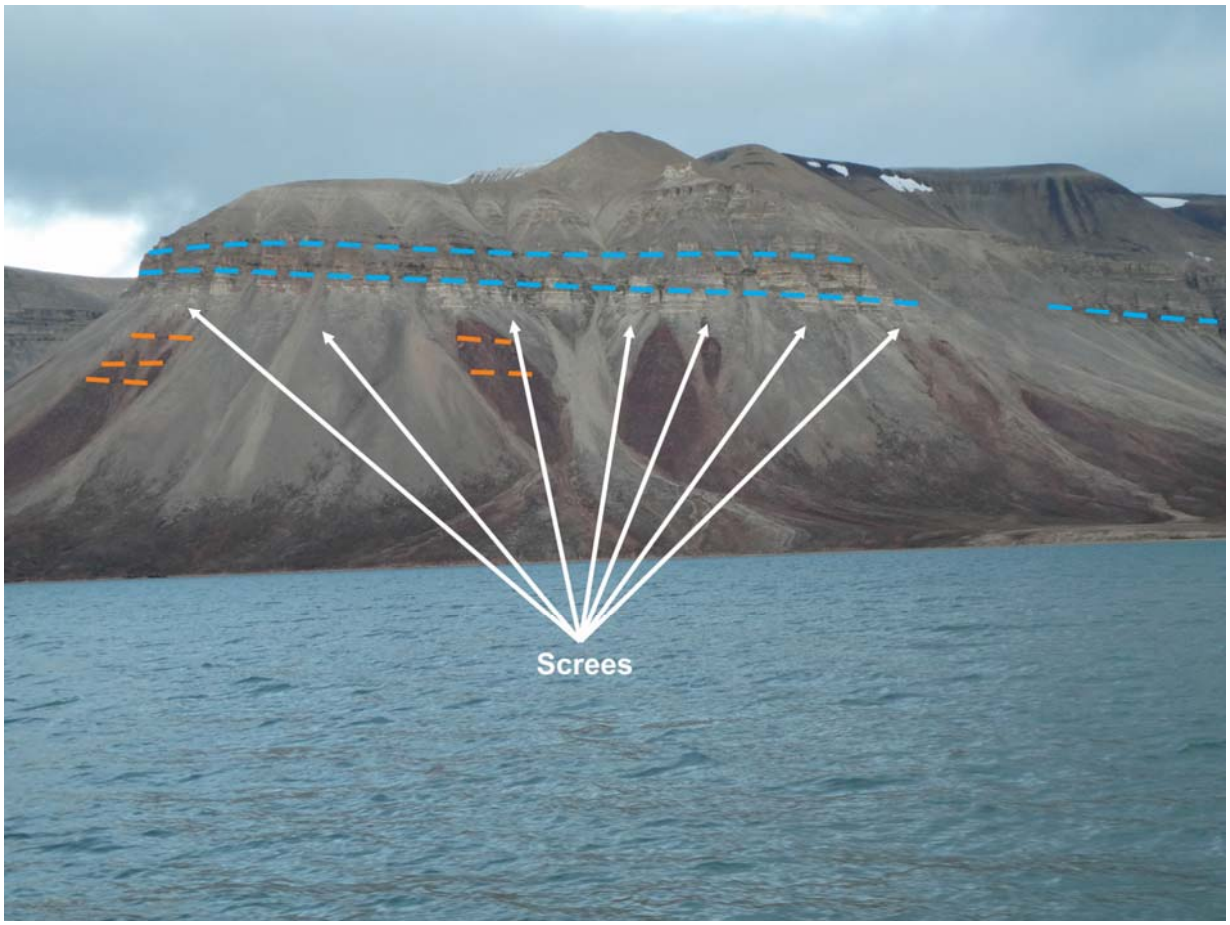

Screes

Figure 25: (a) Interpreted and (b) uninterpreted field photograph showing gently south-dipping (tilted?) to flat-lying and poorly deformed (sub-horizontal bedding surfaces) Lower Devonian strata of the Wood Bay Formation (dashed orange lines) unconformably overlain by flat-lying strata of the Wordiekammen Formation (dashed blue lines) in Bolen (c. 6–7 kilometers southwest of Triungen), and showing that the unconformity is almost completely covered by grey screes of the Wordiekammen Formation. View is towards the east. Photo: Erik P. Johannessen.

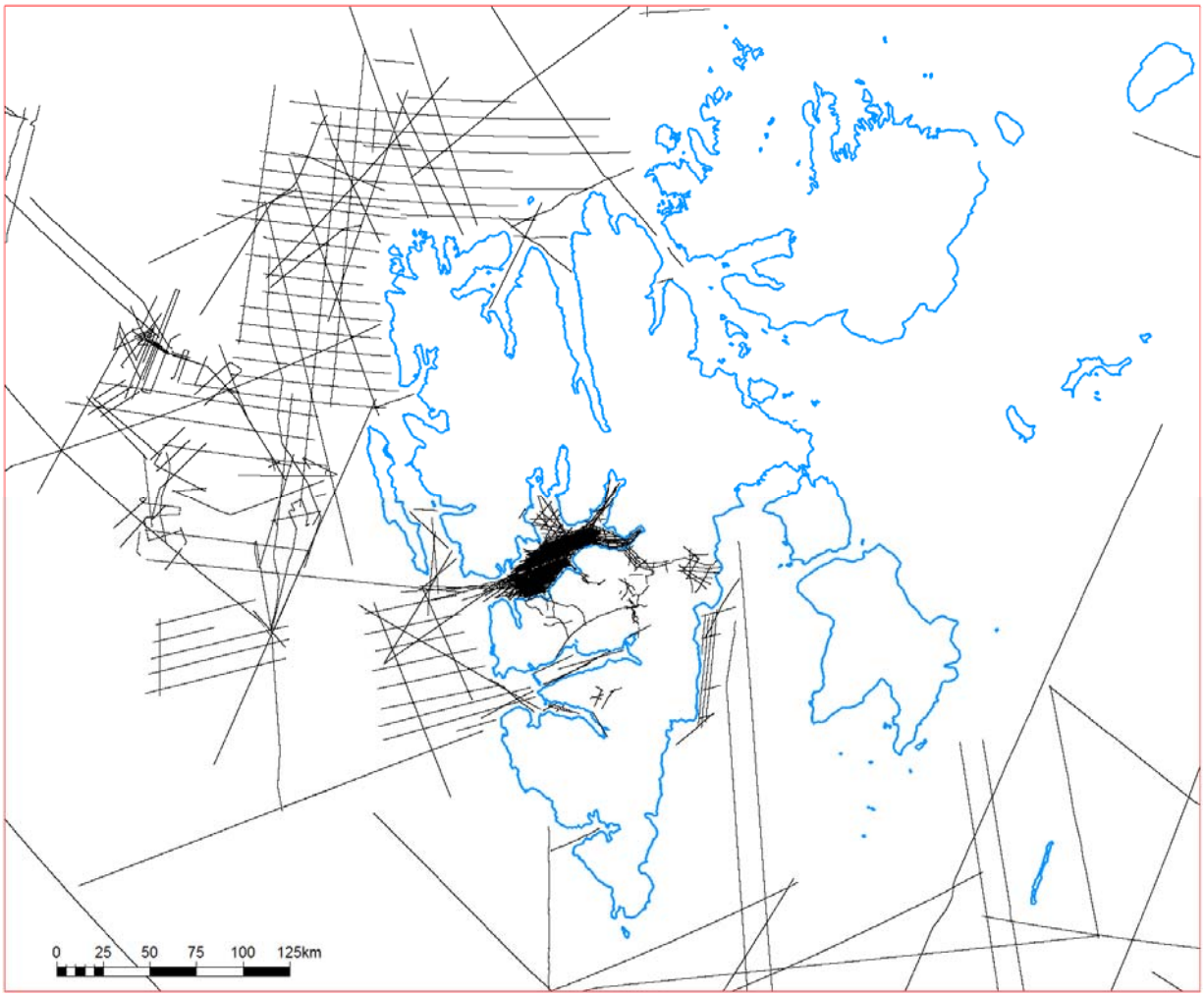


Figure 26: Database of seismic lines (black lines) in Svalbard. The outline of the Svalbard Archipelago is shown in blue.

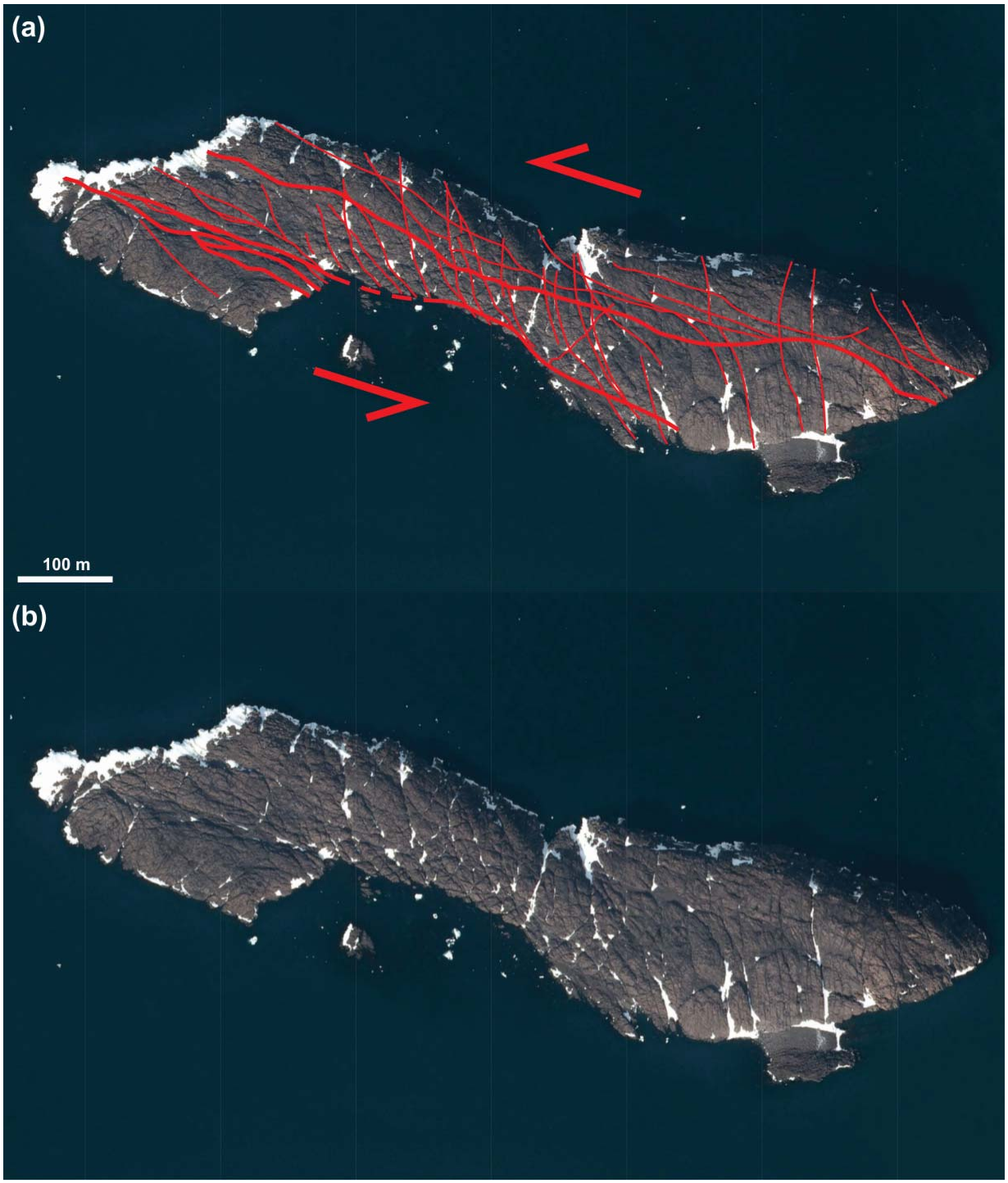
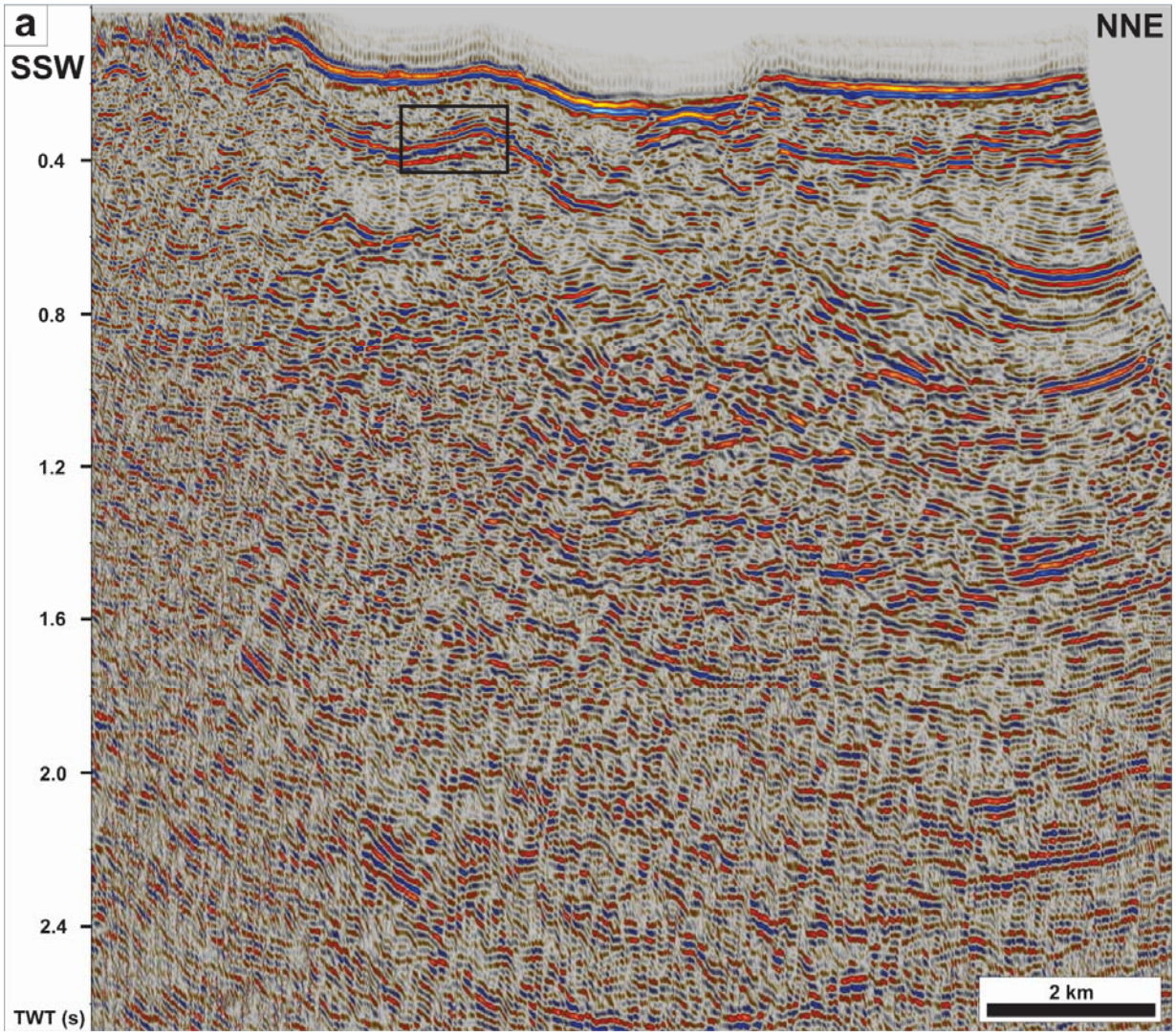


Figure 27: (a) Interpreted and (b) uninterpreted satellite image from toposvalbard.npolar.no showing probable Eurekan, sinistral, brittle shear fabrics within Cretaceous dolerite in Krylen, in Hinlopenstredet (east of Spitsbergen). This suggests that Eurekan deformation affected pervasively every parts of the Spitsbergen island.


a
SSW
NNE
0.4
0.8
1.2
1.6
2.0
2.4
TWT (s)
2 km

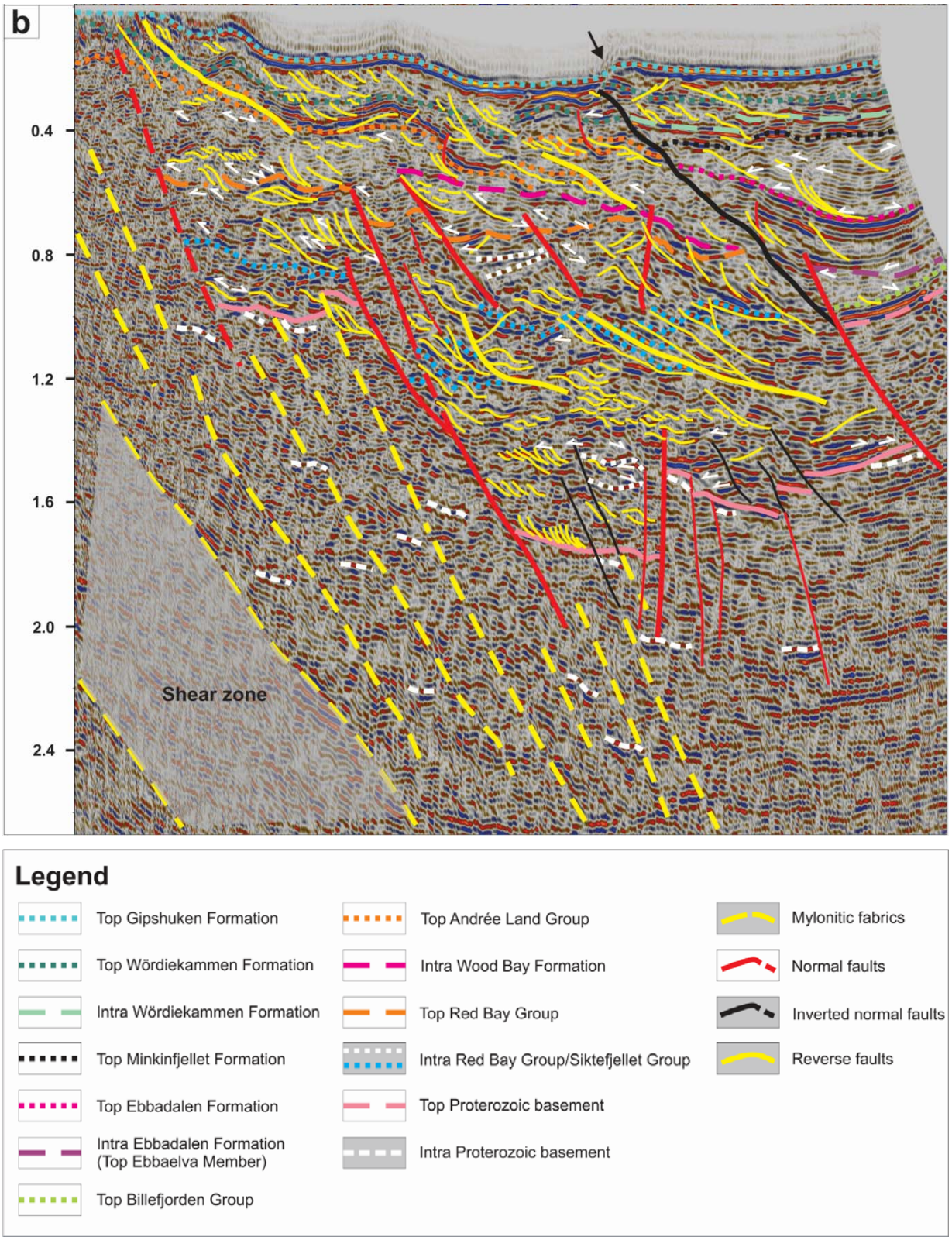


Figure 28: (a) Uninterpreted and (b) interpreted NNE–SSW-trending seismic line in Billefjorden showing the presence of kilometer-thick Lower Devonian deposits of the Siktefjellet–Red Bay groups and Wood Bay Formation deposited along WNW–

ESE-striking Early Devonian normal faults (red lines; e.g., intra Siktefjellet/Red Bay group and intra-Wood Bay Formation growth strata displayed as dotted white and dashed magenta lines) that were inverted during Eurekan deformation (open anticline above major NNE-dipping normal faults) in the footwall of the Balliolbreen Fault (not visible because parallel to this seismic line). The seismic line also shows varying intensity of Eurekan deformation, which appears to be heterogeneously distributed (e.g., plain yellow lines), and localized particularly within Lower Devonian rocks and along stratigraphic boundaries. White arrows show onlapping, toplapping and downlapping seismic reflections. Location shown in Figure 1 as a yellow line.

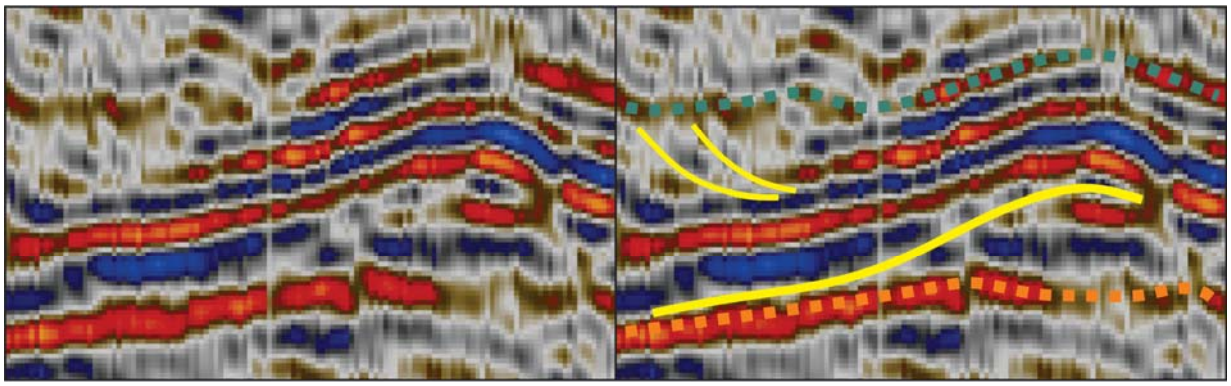


Figure 29: (a) Uninterpreted and (b) interpreted zoom in Figure 28 showing a top-NNE, Eurekan thrust fault (thick yellow line) flattening into a partial décollement localized along the stratigraphic boundary between Lower Devonian rocks of the Wood Bay Formation and strata of the Wordiekammen Formation (dotted orange). Location shown as a white frame in Figure 28a.

Figure 30: (a) Uninterpreted and (b) interpreted outcrop photograph showing poorly deformed sandstone–siltstone-dominated beds within the Lower Devonian Wood Bay Formation just east of Pyramiden. Bedding surfaces are shown as dashed orange lines. Photo: Jean-Baptiste Koehl.

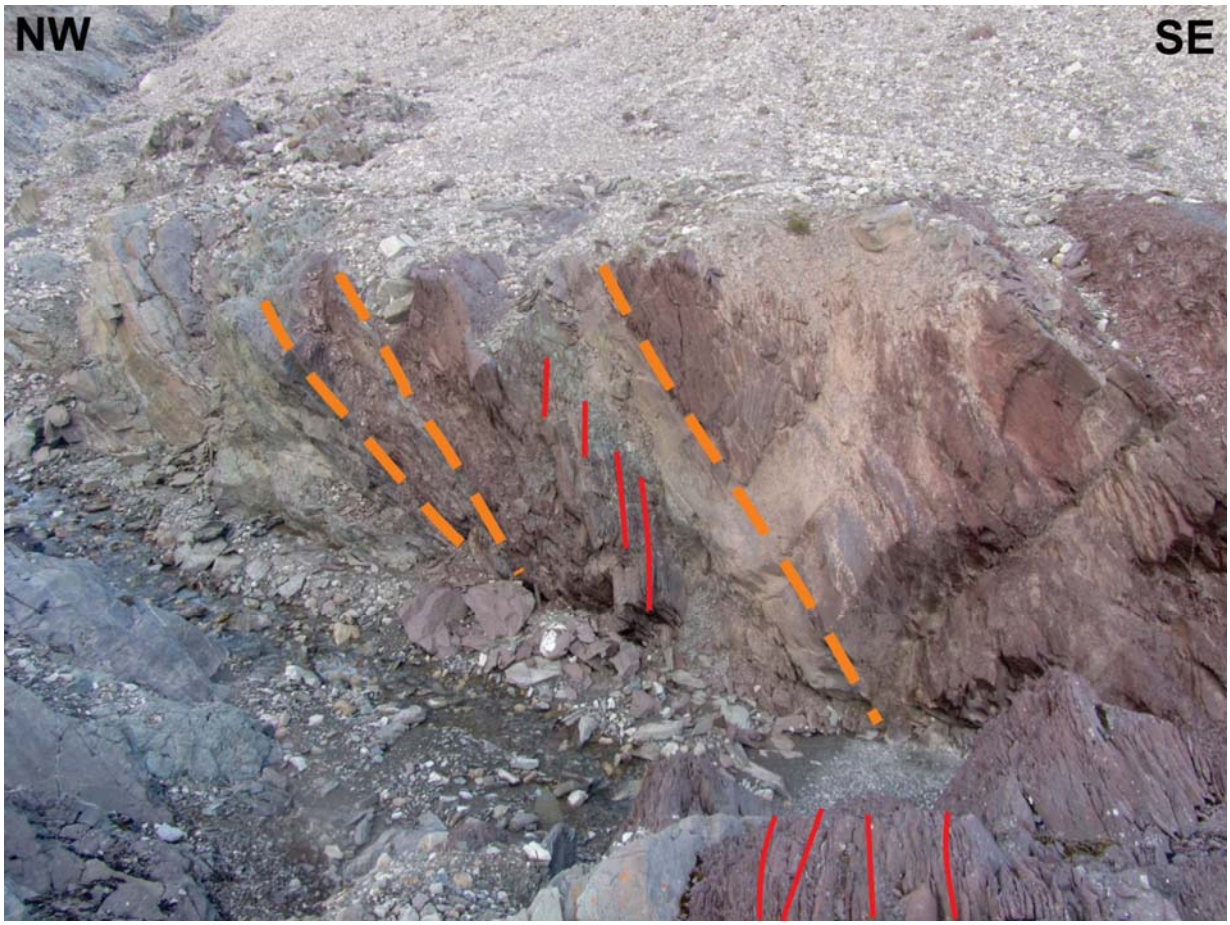


Figure 31: (a) Uninterpreted and (b) interpreted outcrop photograph showing deformed shaly units within the Wood Bay Formation (bedding surfaces are shown as dashed orange lines) affected by cleavage (red lines) and shear surfaces just east of Pyramiden. Note that these beds are located down in the valley, i.e., away from the unconformity with Wordiekammen sedimentary rocks Photo: Jean-Baptiste Koehl.

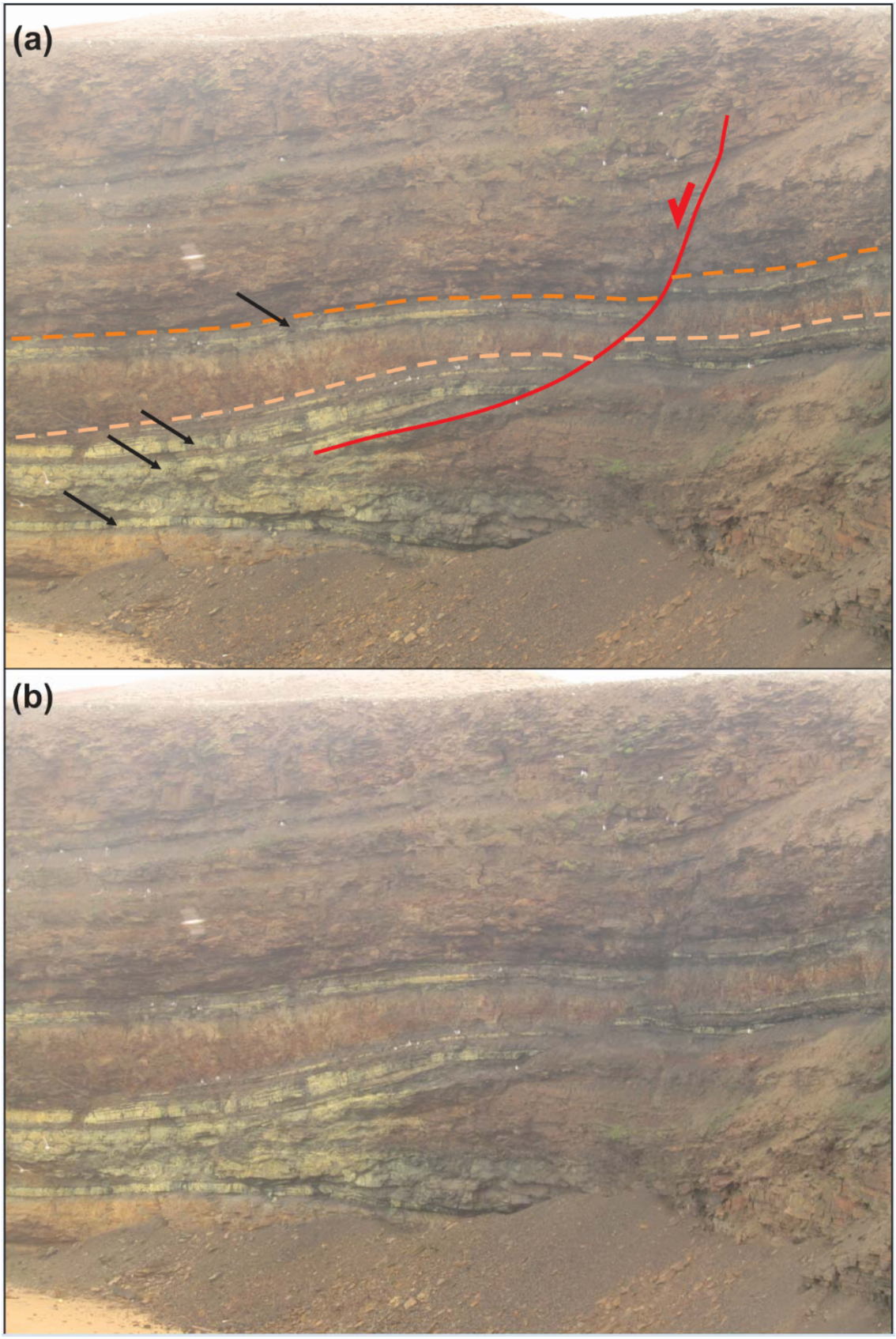

(a)
(b)

Figure 32: (a) Interpreted and (b) uninterpreted field photograph showing a Late Devonian, synsedimentary, listric normal fault soling into a coal-seated décollement within the Rødvika Formation (Billefjorden Group), in northeastern Bjørnøya. This shows the capacity of uppermost Devonian–Mississippian coals of the Billefjorden Group to decouple deformation. Black arrows show yellow-colored layers of coal and dashed orange lines represent stratigraphic markers offset by the fault. Photo: Jean-Baptiste Koehl.