

Review of slope deformations (landslides) hazards in Southern Ethiopia

„from theory to practice“

Petr Kycl

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27.10. 2014



CZECH
GEOLOGICAL
SURVEY



CZECH REPUBLIC
DEVELOPMENT COOPERATION

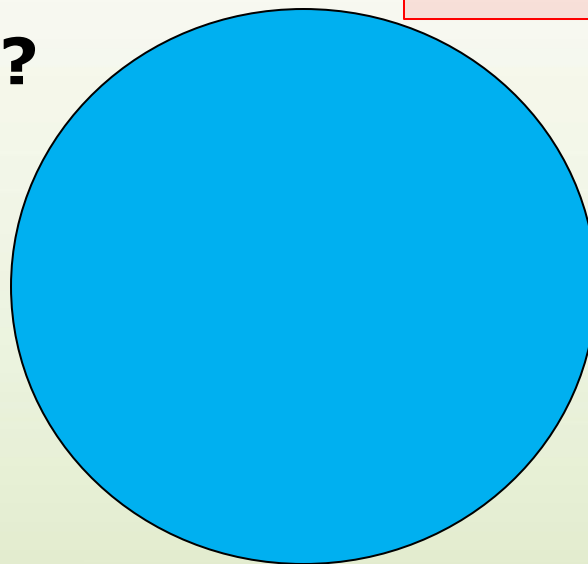


Exogenous processes (geohazards)

**Ground
fissures ??**

Landslides

EG processes
schrinkage - swelling,
collapsibility, suffusion



Alluvial hazards

Karstification



Landslides

Generally, in practice, all varieties of mass movements on slopes, including rock-fall, topples and flows
Some times we used terms as slope movement, mass wasting or mass movement

Basic condition:

Geology – lithological composition (tuffs, clayey material) x structure (cracks, layers)x weathering

Geomorfological setting – inclination of slope

Hydrogeological condition

Trigger:

Climate (heavy rain)

Man-made constructions



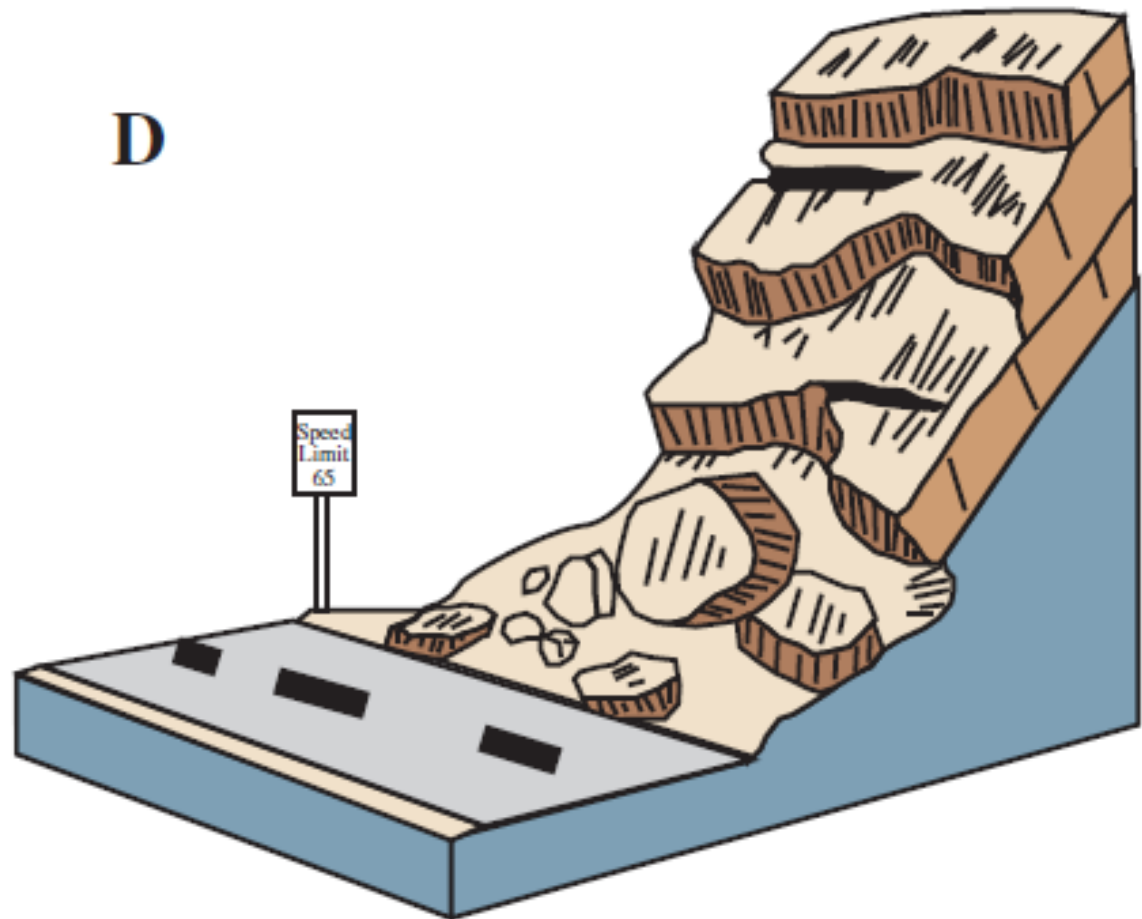
Varnes clasification of landslide types, an update (Hungr – Leroueil – Picarelli 2012)

slope movement	rock	soil
fall	rock fall (1)	boulders, debris, silt fall (2)
topple	rock block topple (3)	gravel, sand, silt topple (5)
	rock flexural topple (4)	
slide	rock rotational slide (6)	clay, silt rotational slide (11)
	rock translational slide (7)	clay silt translational slide (12)
	wedge slide (8)	gravel, sand, debris slide (13)
	rock compound slide (9)	clay silt compound slide (14)
	rock collapse (10)	
spread	rock slope spread (15)	sand, silt liquefaction spread (16)
		sensitive clay spread (17)
flow	rock avalanche (18)	sand, silt, debris dry flow (19)
		sand, silt, debris flow slide (20)
		sensitive clay flow slide (21)
		debris flow (22)
		mud flow (23)
		debris flood (24)
		debris avalanche (25)
		earth flow (26)
slope deformation	mountain slope deformation (28)	soil slope deformation 30)
	rock slope deformation (29)	soil creep (31)
		solifluction (32)



falls

The material descends largely through the air by falling, saltation or rolling

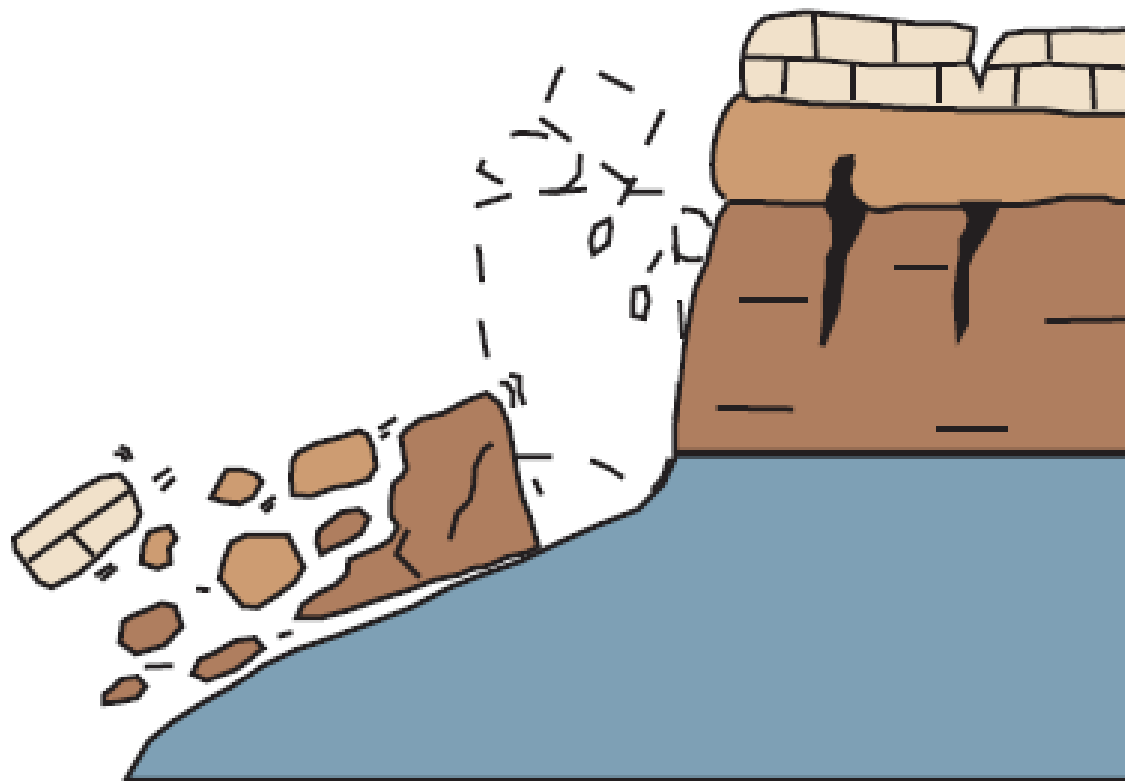


Rockfall



topple

Rotation out of the slope of a mass of rock about point or axis



Topple



Area of occurrence: Weransa Ridge - Caldera scarp south of Shashamene



The scarp is 100–300 m high and about 4 km long. The slopes are formed by rhyolite and blocky rhyolitic ignimbrite. Both lithologies are characterized by columnar jointing which predisposes the decomposition of the rocks and slope movement.



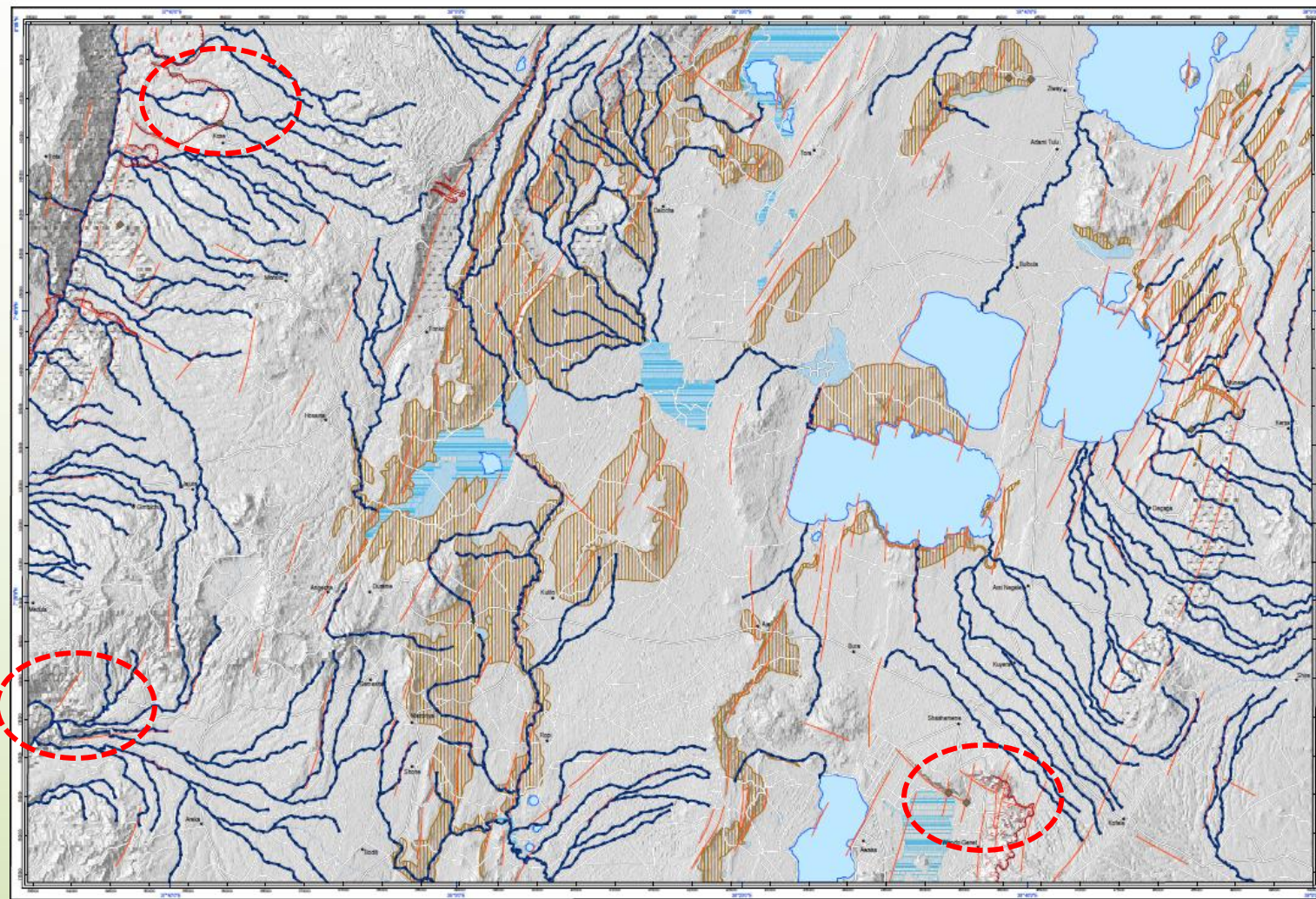
The thickness of old rock-fall deposits on the foothills could exceed 50 m.

Blocks bigger than 3 m and volume about 30 m³.

GEOHAZARD MAP OF HOSAINA NB 37-2

Editor: V. Rappich

Sheet NB37-2 Hosaina



MAP SHEET INDEX

1: 250,000



- LEGEND**
- ENDOGENOUS GEOHAZARDS**
- VOLCANIC HAZARDS**
- 1 Area, where eruption of central volcano would deposit more than 30 cm of pyroclastic ash (level hazard)
 - 2 Area with presence of volcano-magma monogenic volcanoes, where locally would be deposited during eruption more than 30 cm of pyroclastic material
 - 3 Volcano centre (active volcano)
 - 4 Volcano-magma monogenic volcanoes
- SEISMIC HAZARDS**
- 5 This accumulation of earthquakes amplifying seismic effects
 - 6 Area of documented or potential occurrence of ground failure (subsidence and tilting)
 - 7 Faults
 - 8 EARTHQUAKE EPICENTERS with given year (before 1980)
 - 1972 4.0 - 5.0
 - 1944 5.1 - 6.0
 - 1985 6.1 - 7.0
 - 9 EARTHQUAKE EPICENTERS with given year (after 1980)
 - 1991 4.0 - 5.0
 - 2010 5.1 - 6.0
- EXOGENOUS GEOHAZARDS**
- EROSION-RELATED HAZARDS
 - 10 Watercourse/cut-off erosion (pavement)
 - 11 Stream erosion (gully and bank erosion)

ACCUMULATION-RELATED HAZARDS

 - 12 Rapid sediment accumulation

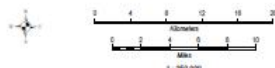
SLOPE DEFORMATION HAZARDS

 - 13 Steep slope prone to rock fall, debris flow and landslides
 - 14 Landslide
 - 15 Main landslide scarp
 - 16 Debris flow
 - 17 Roadcut

HYDROLOGICAL HAZARDS

 - 18 Inundation and degradation of sediments**

Geological map of Hosaina sheet NB 37-2 at Scale 1: 250,000
Editor: V. Rappich
Collaborators: T. Hroch, P. Hrdý, J. Mlýn, K. Váňa
Digitized cartography: D. Čížek, R. Japaneček

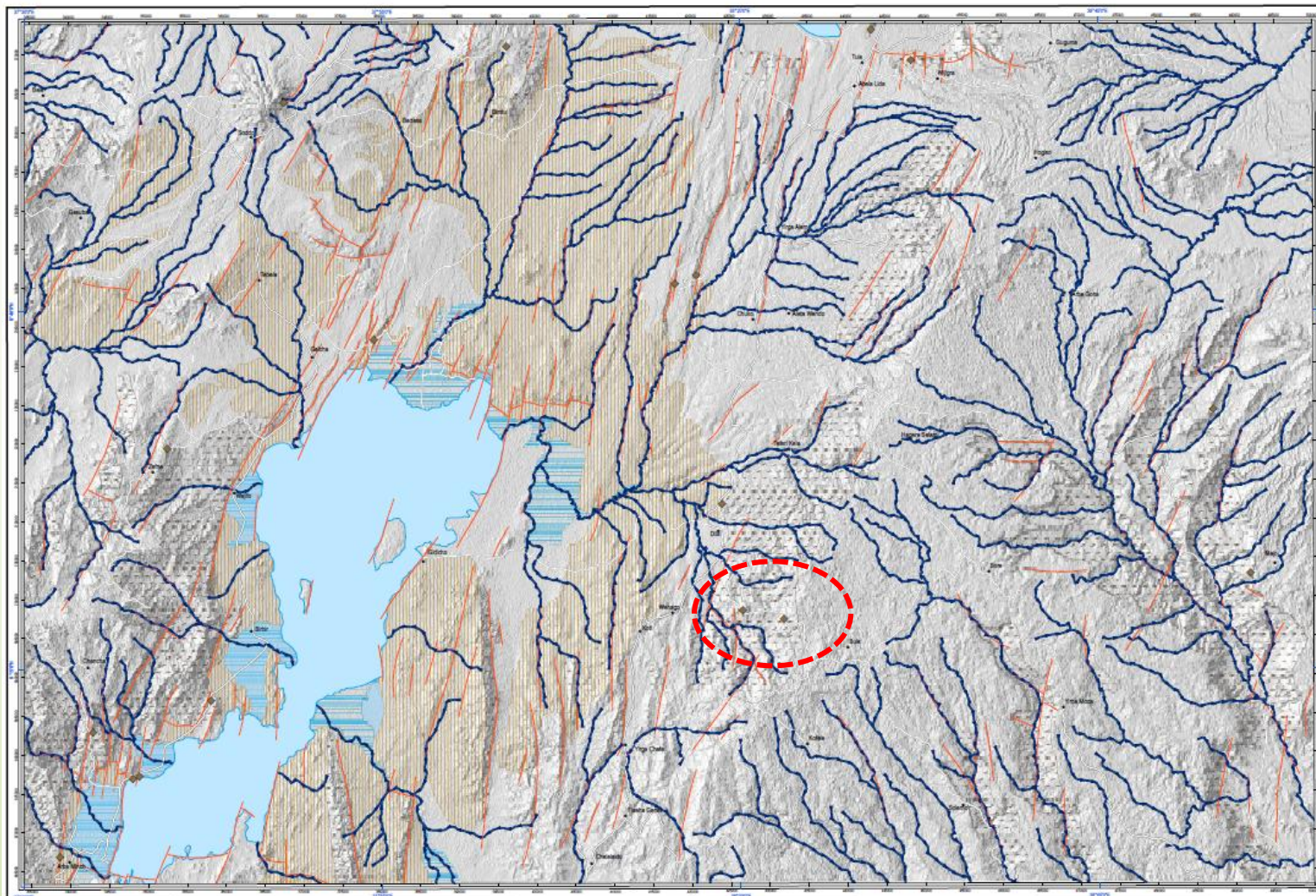


Coordinate system:
Blue reference: WGS84 UTM
Black reference: Adhunik UTM, zone 37 N
Projection: Transverse Mercator
Ellipsoid: Czech 1985, Adhunik

GEOHAZARD MAP OF DILA NB 37-6

Editor: V. Rapprich

Sheet NB 37-6 Dila



Geological map of Dilsheer MB 37-6 at Scale 1 : 250,000
Editor: V. Rappich
Collaborators: T. Horsch, P. Wyl, J. Müller, J. Malik, K. Verwe
Digital cartography: G. Cölbe, P. Hajmásková

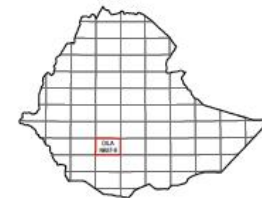


Coordinate system:
Blue numbers: longitude & latitude
Black numbers: Adirond UTM - zone 17 in m
Projection: Transverse Mercator
Ellipsoid: Clarke 1866, Adirond



MAP SHEET INDEX

1 : 250,000



LEGEND
ENDOGENEOUS GECHAZARDS
LOCAL CLIMATE AND TOPOGRAPHY

VULCANIC HAZARDS

- 1  Area with presence of Holocene mafic monogenetic volcanoes, where locally would be deposited during eruption more than 50 cm of pyroclastic material

SEISMIC HAZARDS

- 4  Thick accumulations of sediments amplifying seismic effects
- 5  Area of documented or potential occurrence of ground fissures (moderate strength)
- 6  Fault

- 7 EARTHQUAKE EPICENTER with given year (before 1900).

- | | Magnitude |
|---------|-----------|
| ☆ 573 | 4.5-5.0 |
| ☆☆ 544 | 5.1-6.0 |
| ☆☆☆ 553 | 6.1-7.0 |

8. EARTHQUAKE EPICENTER with given year (after 1900)
 Magnitude
 1991 4.0-5.0
 2010 5.1-6.0

EXOGENOUS GEOHAZARDS

EROSION-RELATED HAZARDS

-  Widespread surface erosion (bedrock)
-  Stream erosion (gully and lateral erosion)

ACCUMULATION-RELATED HAZARD

- 

95.0% REPRODUCIBILITY HAS BEEN

- 12  Steep slopes prone to rock fall, debris flows and landslides

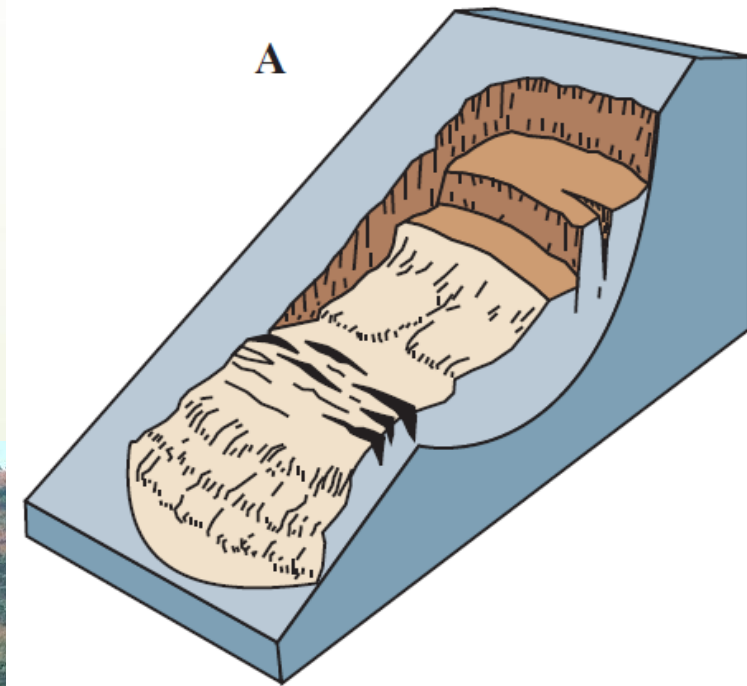
[illegible]

- 14 Inundation and aggradation of sediments



slide

Downslope movement of soil or rock mass occurring dominantly on surfaces of rupture (shear zone)



Rotational landslide

Area of occurrence:
Gibe valey, Dorze



Ameka Landslide – 3D view



Classification:

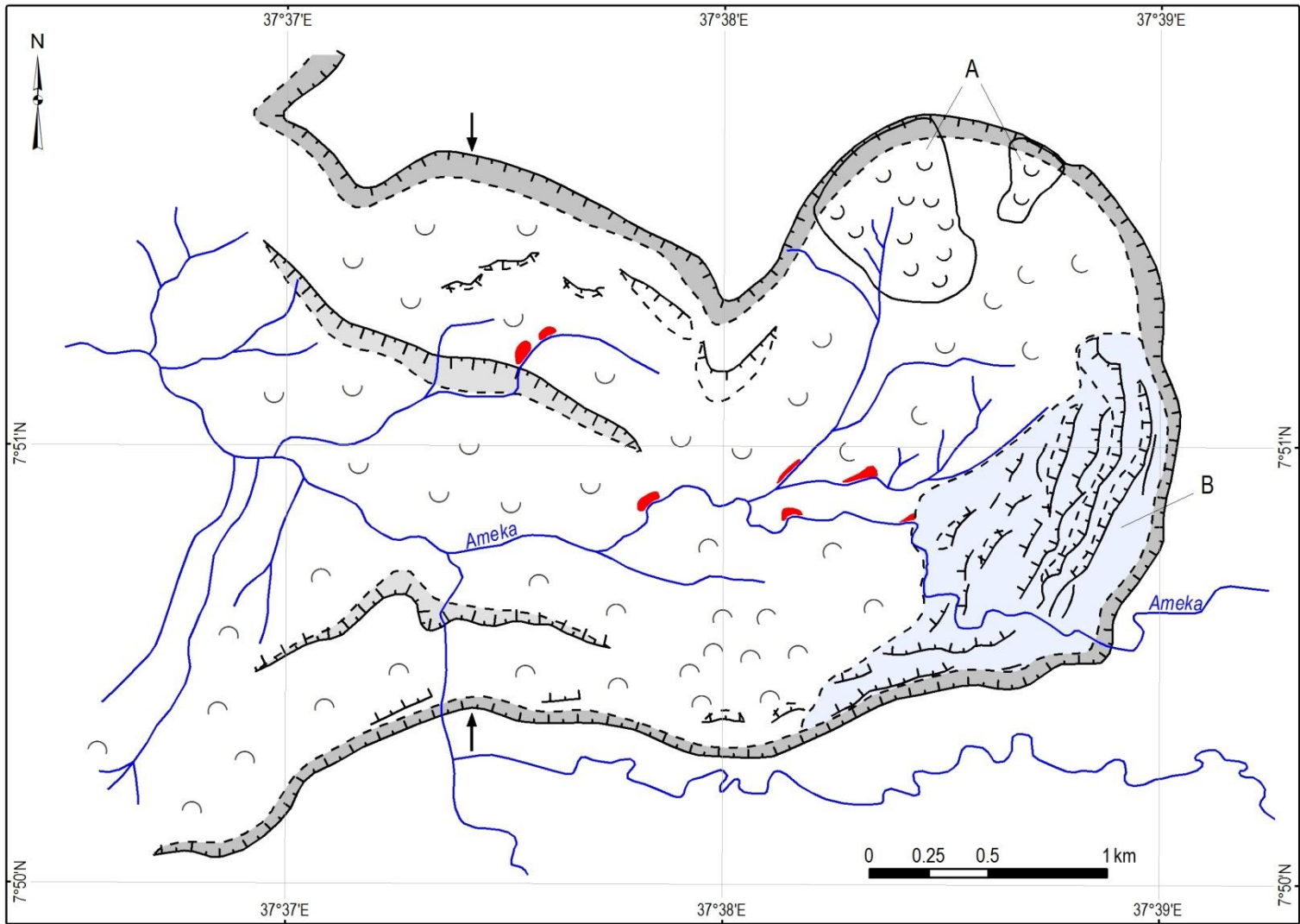
Deep seated gravitational slope deformation **rock rotational slide** (rock compound slide) „Varnes update“





Basic data

- documented dimensions 4,5 x 2,5 km
- causes – tectonic settings and erosion of Ameka River
- geology – bazalt nad tufs in base covered by ignibrits
ryolit, trachyt and tufs = sandwich structure
- vertical distance - 450 mts
- damages – still nothing, in case activity some tukuls
- slide blocks in dimension 900 m wide and 200 m long
- from main scarp waterfalls (Bischo falls, Ameka falls)



old main scarps - 1st generation



old main scarps - 2nd generation



old block deformations (block slide)



old landslide deformations - 1st and 2nd generation



younger slope deformations (3rd generation)



recent slope deformation (activated by stream erosion)



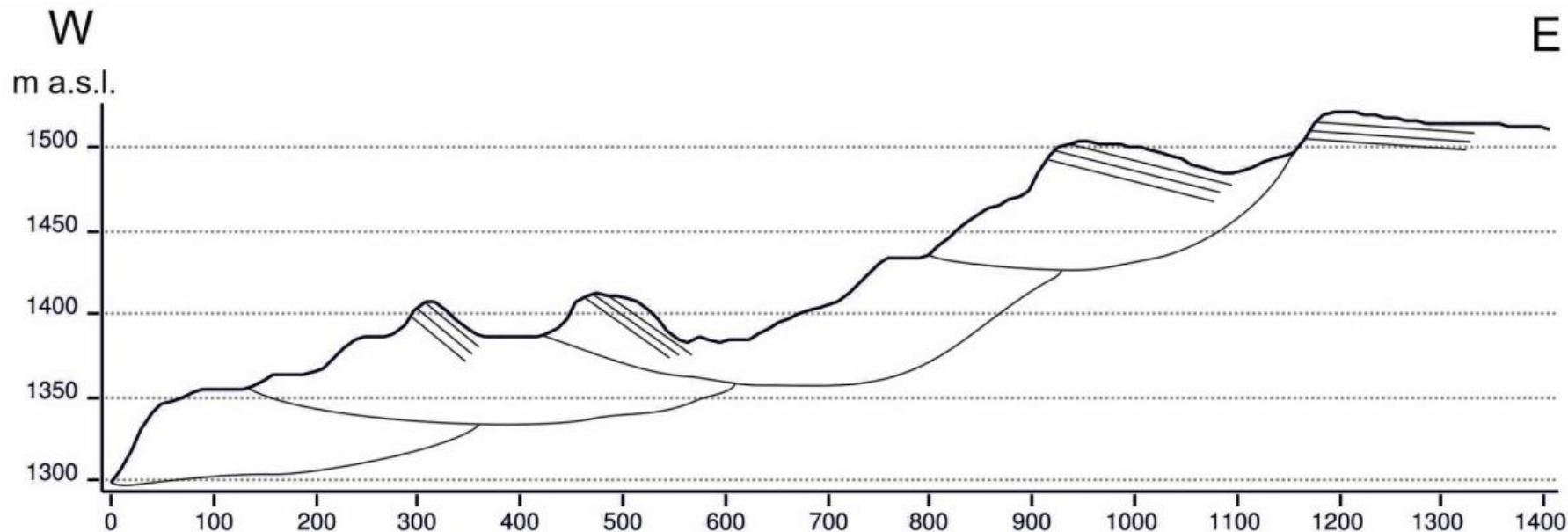
streams



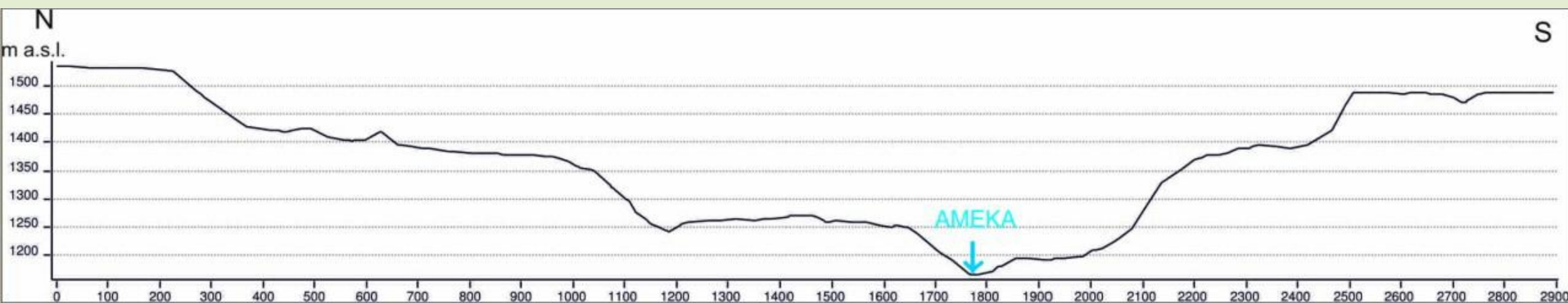


Crosssections

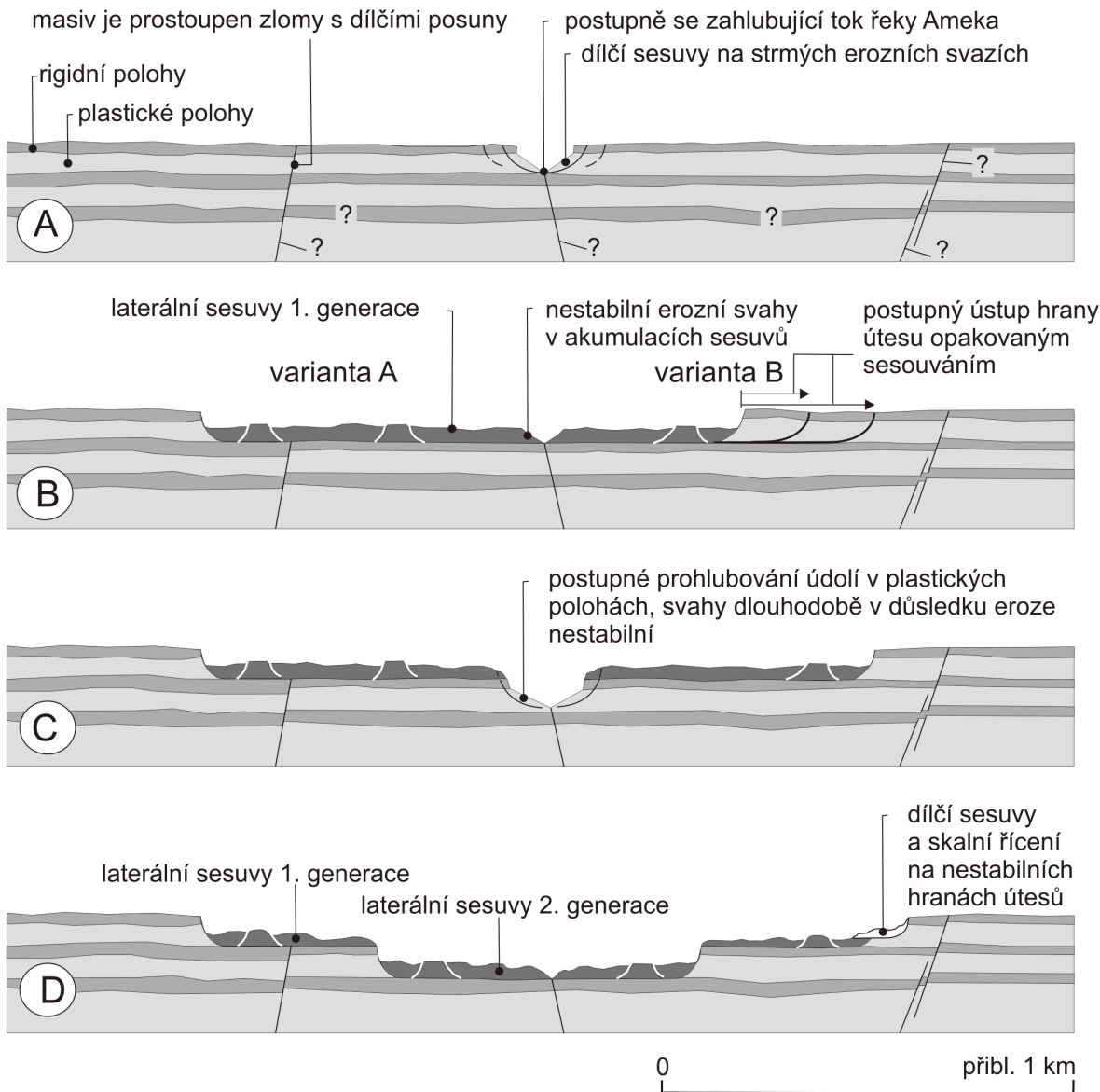
1 - 1' - block deformation B



2 - 2'









Results, recommendations

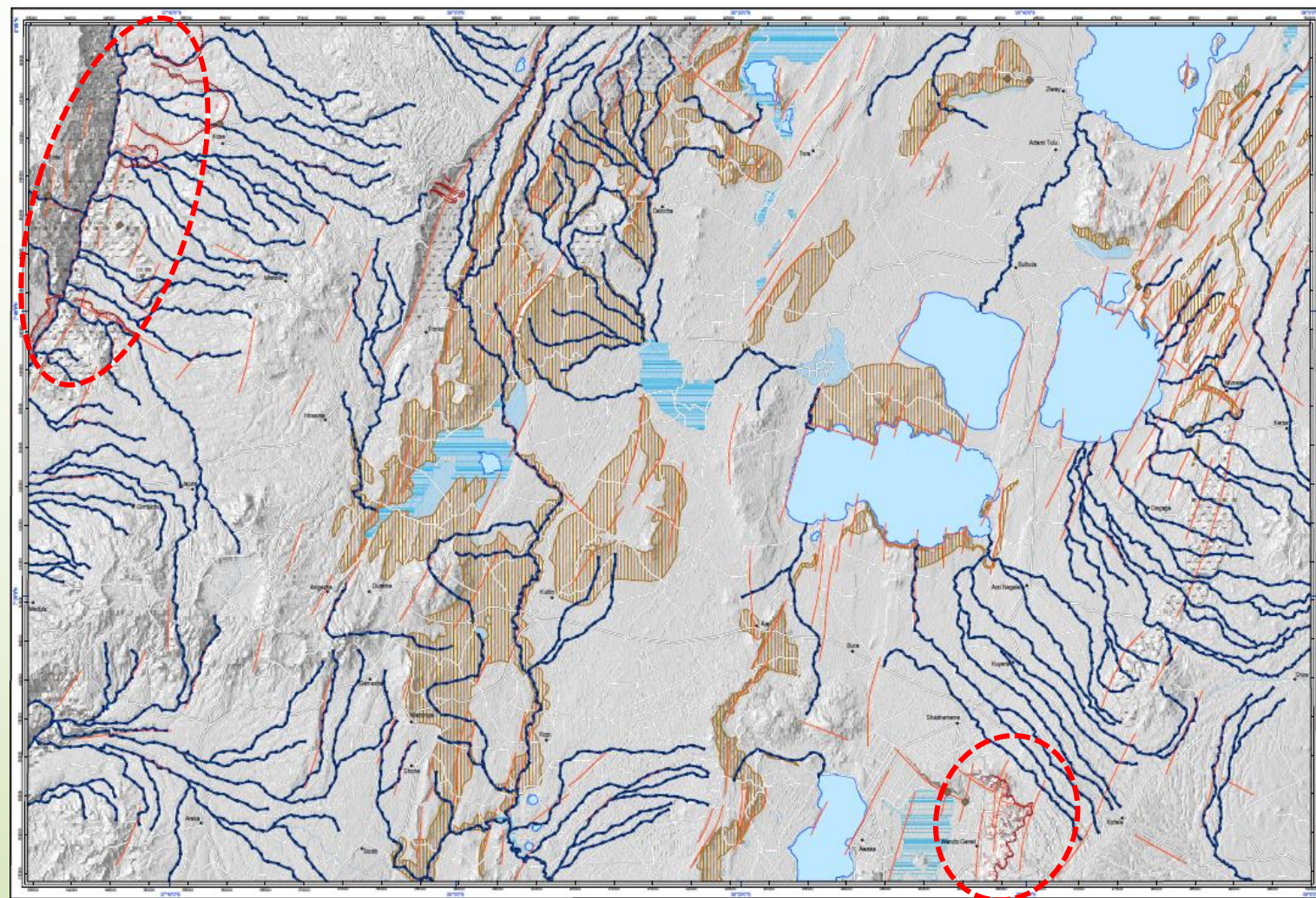
- the whole area of landslide is potentially susceptible to such phenomena (sliding) = necessary indicate as a risk zone



GEOHAZARD MAP OF HOSAINA NB 37-2

Editor: V. Rappich

Sheet NB37-2 Hosaina



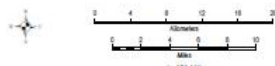
MAP SHEET INDEX

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 - 2 Area with presence of volcano-magma monogenic volcanoes, where locally would be deposited during eruption more than 30 cm of pyroclastic material
 - 3 Volcano centre silico volcano
 - 4 Volcano centre magma monogenic volcano
- SEISMIC HAZARDS**
- 5 This accumulations of sediments amplifying seismic effects
 - 6 Area of documented or potential occurrence of ground failure (subsidence and tilting)
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- 10 Watercourse surface erosion (badlands)
 - 11 Stream erosion (gully and bank erosion)
- ACCUMULATION-RELATED HAZARDS**
- 12 Reptile sediment accumulation
- SLOPE DEFORMATION HAZARDS**
- 13 Steep slope prone to rock fall, debris flow and landslides
 - 14 Landslides
 - 15 Main landslide scarp
 - 16 Debris flow
 - 17 Boulder
- HYDROLOGICAL HAZARDS**
- 18 Incrustation and aggradation of sediments

Geological map of Hosaina sheet NB 37-2 at Scale 1 : 250,000
Editor: V. Rappich
Contributors: T. Hroch, P. Hrdý, J. Mikš, K. Váňa
Digitized cartography: D. Čížek, R. Japaneček



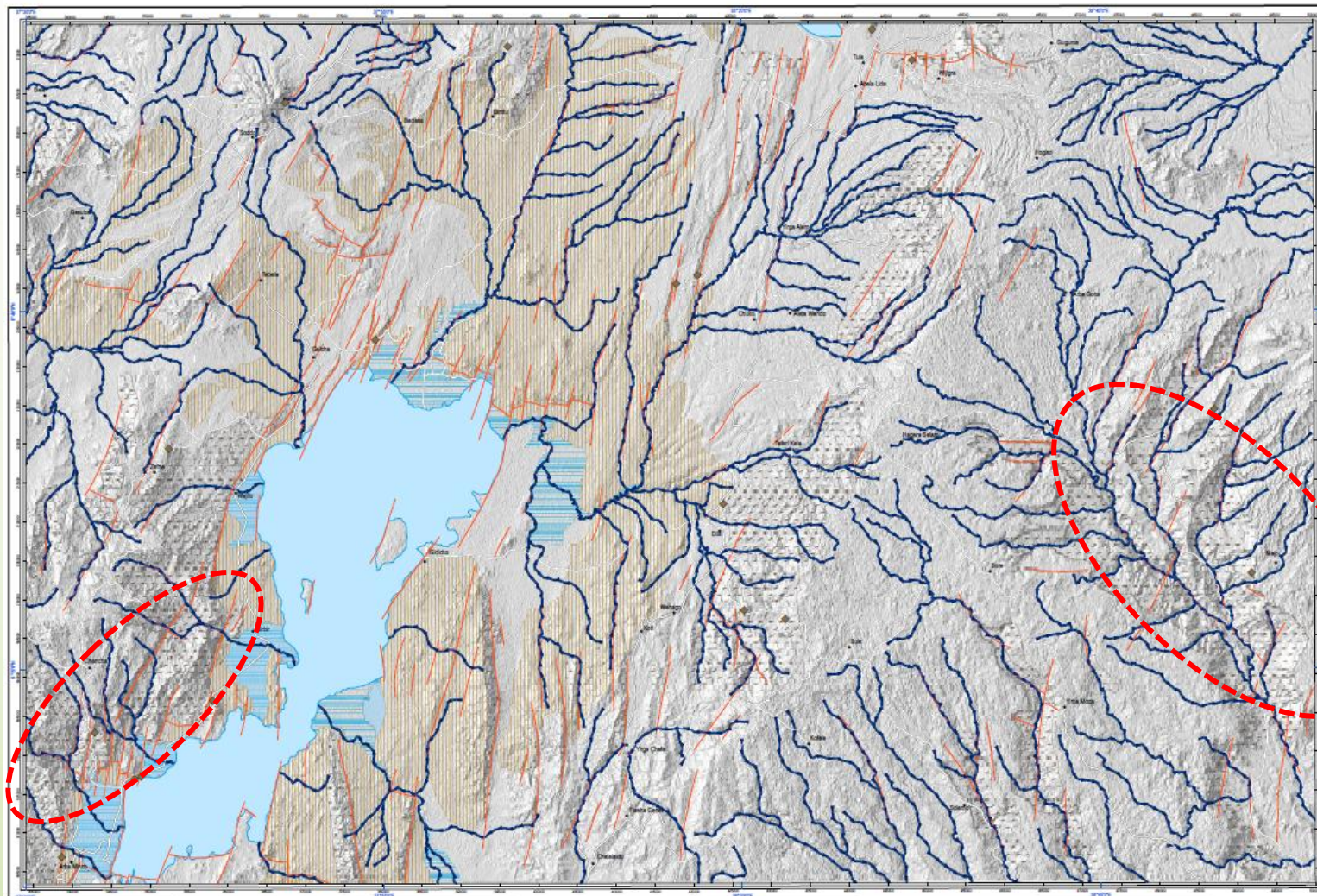
Coordinate system:
Blue reference: WGS84 UTM
Black reference: Adhunik UTM, zone 37 N
Projection: Transverse Mercator
Ellipsoid: Czech 1985, Adhunik



GEOHAZARD MAP OF DILA NB 37-6

Editor: V. Rappich

Sheet NB 37-6 Dila



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 - 2 Volcanic tectonic structures
 - 3 Volcanic tectonic structures
- SEISMIC HAZARDS**
- 4 Thick accumulations of sediments amplifying seismic effects
 - 5 Area of documented or potential occurrence of ground features (provide anchorage)
 - 6 Faults
 - 7 EARTHQUAKE EPICENTERS with given year (before 1900)
 - 8 EARTHQUAKE EPICENTERS with given year (after 1900)
- EXOGENOUS GEOHAZARDS**
- EROSION-RELATED HAZARDS**
- 9 Waterlogged surface erosion (bedrock)
 - 10 Stream erosion (gully and lateral erosion)
- ACCUMULATION-RELATED HAZARDS**
- 11 Rapid sediment accumulation
- SLOPE DEFORMATION HAZARDS**
- 12 Steep slopes prone to rock fall, debris flows and landslides
 - 13 Rockfall
- HYDROLOGICAL HAZARDS**
- 14 Foundation and aggradation of sediments



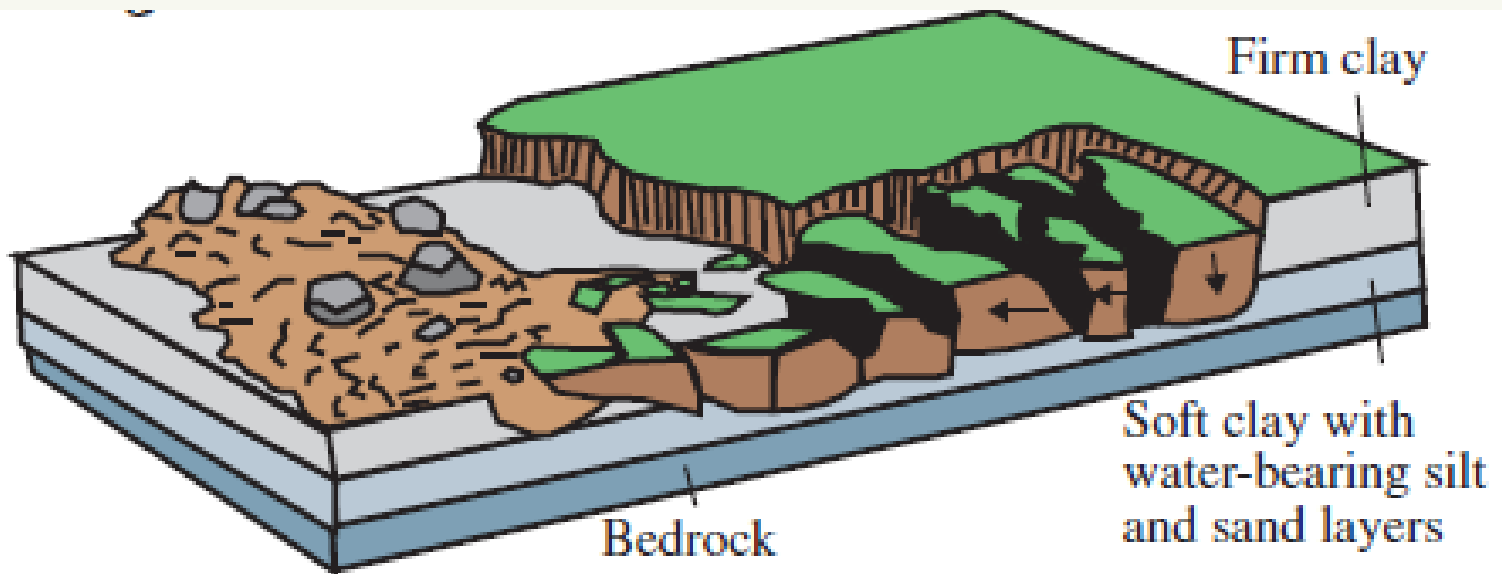
1: 250 000





spread

Extension of a cohesive soil or rock mass combined with general subsidence of the mass into softer underlying material



Lateral spread



Approximately 2 km south of Belela village, 40 km southwest of Hawasa city, was located very impressive slope movement which can be described as “lateral spread”



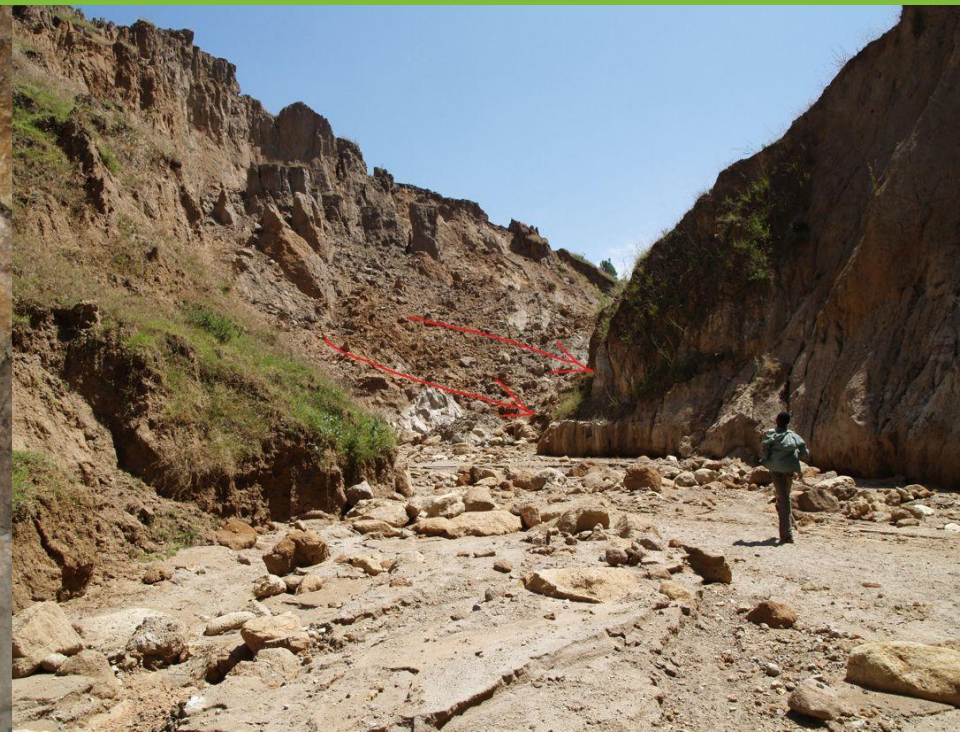
typical horst-and-graben features at the head with



rock mass

softer underlying material

The basal segment of the shear zone in this case follows a weak horizon of paleosols



- The area is extending to 300x 200 m and out of settlement.
- Many secondary shear surfaces, active, developing but no risky for infrastructure.
- The main scarp of lateral spread is more than 10 m high and outcrop shows low compacted ignimbrites which may be seen as soil.
- The masses of body pushed the stream channel, stream was temporarily damned and part of channel has created temporary lake.



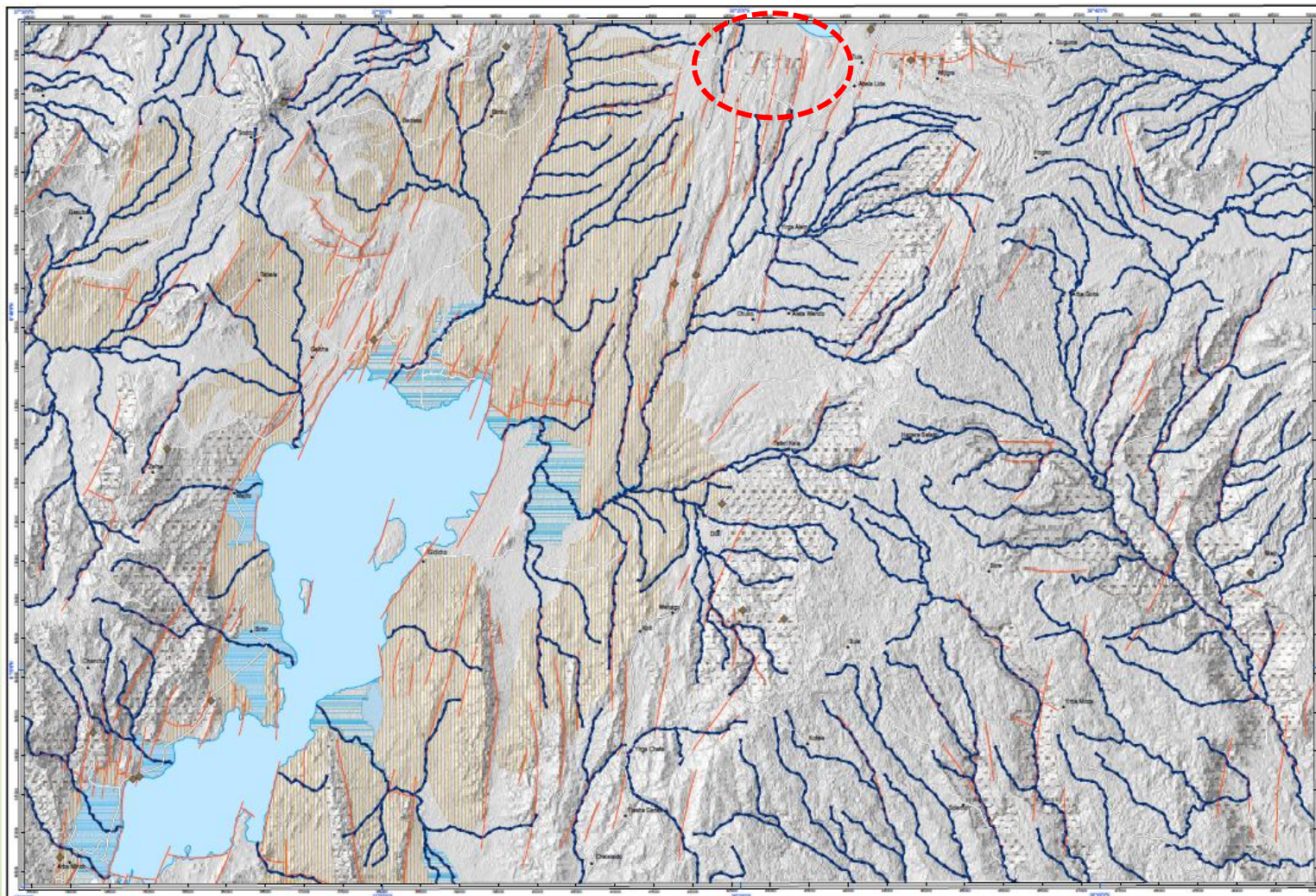
On surface in the foreground of movements we documented on November 2013 open cracks. On April 2014 was movements more extended.



GEOHAZARD MAP OF DILA NB 37-6

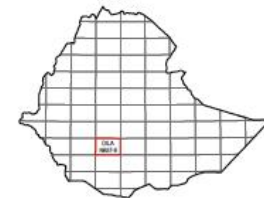
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Sheet NB 37-6 Dila



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- EXOGENOUS GEOHAZARDS**
- EROSION-RELATED HAZARDS
 - 9 Intersected surface erosion (bedrock)
 - 10 Stream erosion (gully and lateral erosion)

ACCUMULATION-RELATED HAZARDS

 - 11 Rapid sediment accumulation

SLOPE DEFORMATION HAZARDS

 - 12 Steep slopes prone to rock fall, debris flows and landslides
 - 13 Rockfall

HYDROLOGICAL HAZARDS

 - 14 Foundation and aggradation of sediments**

Geological map of Dila sheet NB 37-6 at scale 1 : 250 000
Editor: V. Rappich
Cooperation: J. Rappich, J. Rappich, J. Rappich, J. Rappich, J. Rappich
Digital cartography: J. Rappich, J. Rappich



Coordinate system:
Blue horizontal coordinate & vertical
Blue horizontal coordinate: UTM zone 37N
Projection: Transverse Mercator
Datum: Czech datum 1949, datum

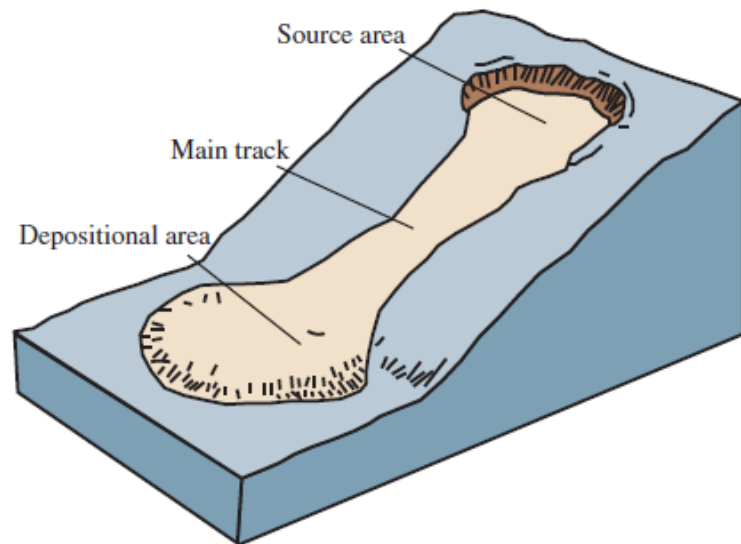


flow

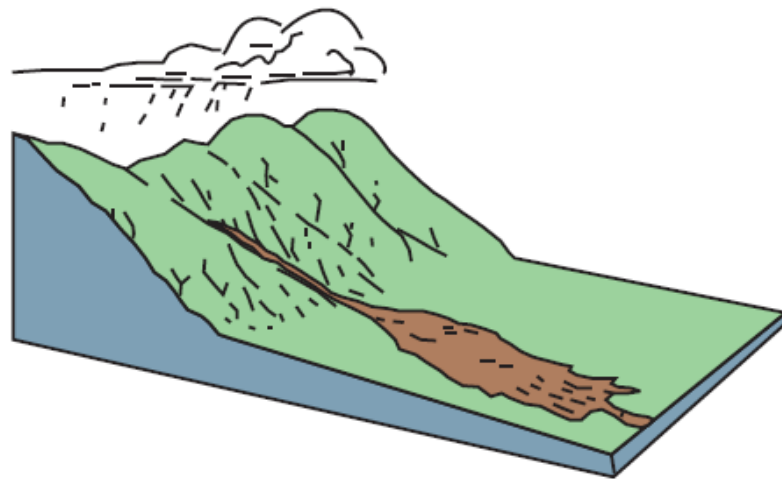
moving mass of loose mud, sand, soil, rock, water and air that travels down a slope under the influence of gravity

Area of occurrence: MER scarp

H



Earthflow

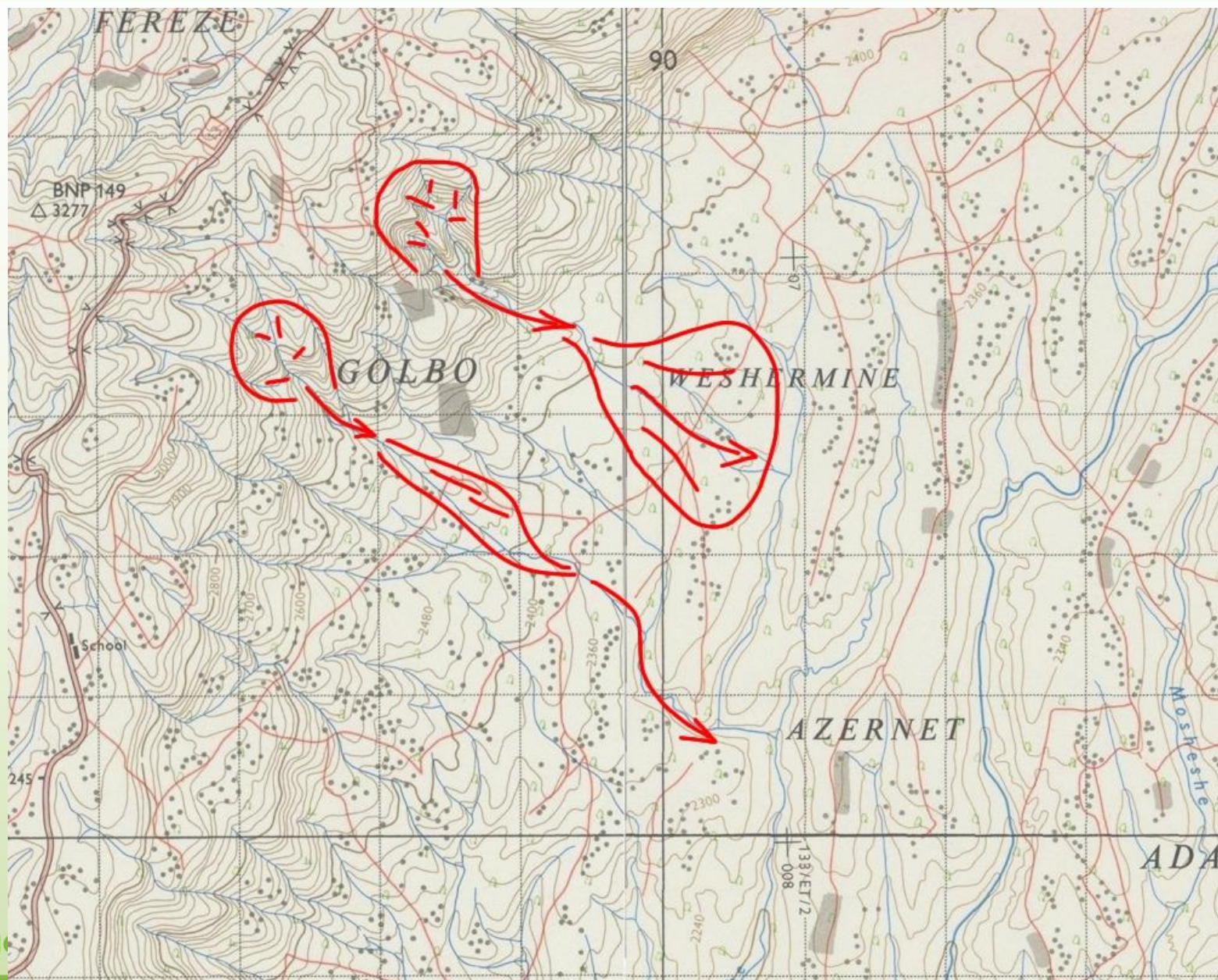


Debris flow



Golbo Debris flow 1 and 2 – Google Earth







Classification:

debris flow

exceptionally blocks
of more than 10 m³



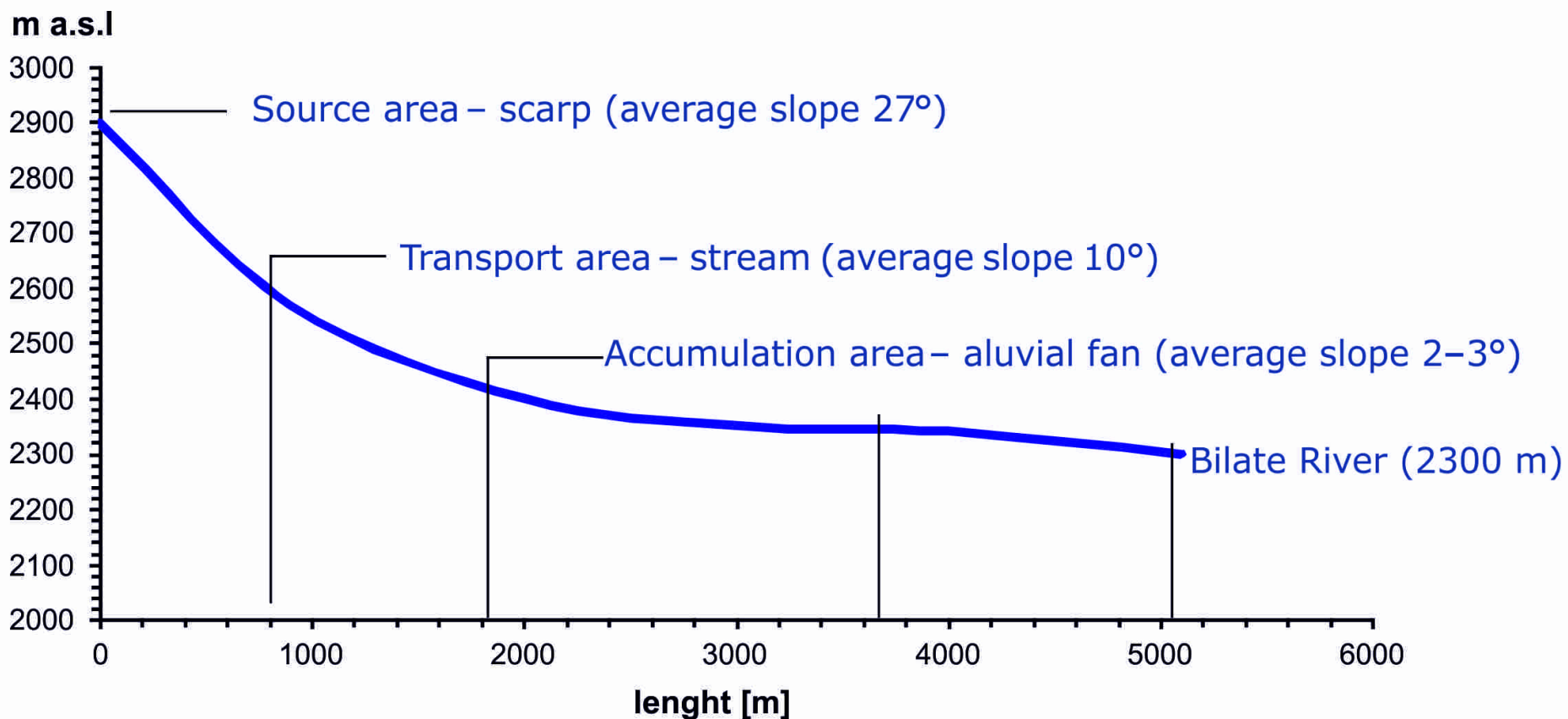


Basic data

- documented dimensions - 3,6 x 1 km
- causes – tectonic settings and weathering
- trigger – heavy rains
- geology – ignimbrites, highly weathered
- vertical distance 600 mts
(2900 - 2300 m a.s.l.)
- damages - ??? data from the locals not reliable
- dating – unclear date of origin (probably repeatedly)
- difficult access for other measurement



Profile of the Golbo debris flow





Results, recommendations

- the whole area of main rift slopes is potentially susceptible to such phenomena (flows)
= necessary indicate as a risk zone
- flows - high risk phenomenon
- is missing of land use planning for the construction
- restrict the construction of houses, tukuls, roads
- especially the foot of the slopes under erosion gully



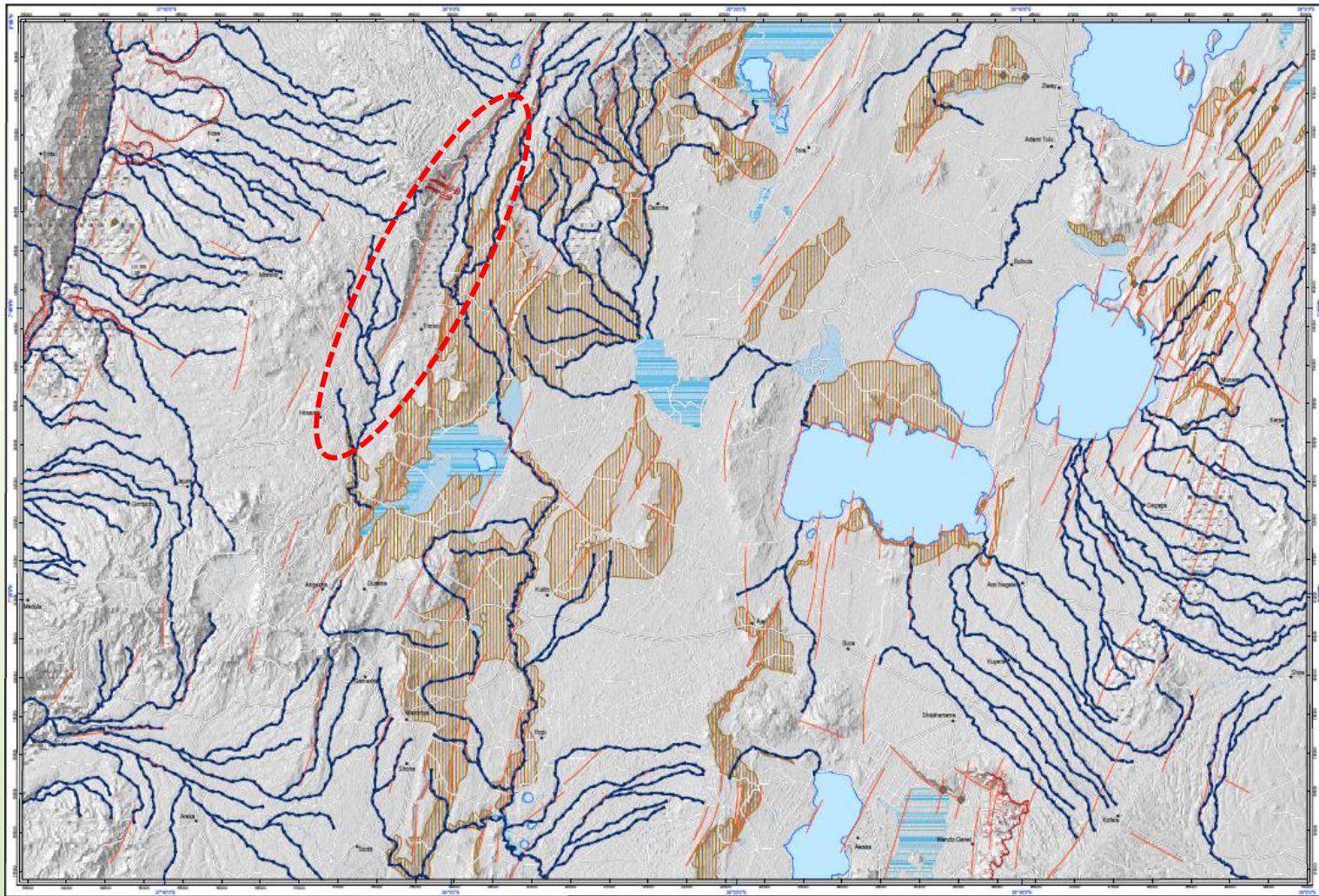




GEOHAZARD MAP OF HOSAINA NB 37-2

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Sheet NB37-2 Hosaina



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- 1 Area, where eruption of central silico volcanic would deposit more than 30 cm of pyroclastic ash or lava material
 - 2 Area with presence of volcano-meltic monogenetic volcanoes, where locally would be deposited during eruption more than 30 cm of pyroclastic material
 - 3 Volcanic centre silico volcano
 - 4 Volcanic centre meltic monogenetic volcano
- SEISMIC HAZARDS**
- 5 This accumulations of sediments amplifying seismic effects
 - 6 Area of disjunctures or potential existence of ground fissures (fractures and logs)
 - 7 Faults
 - 8 EARTHQUAKE EPICENTERS with given year (before 1900)
 - 1872 Magnitude: 4.0 - 5.0
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SLOPE DEFORMATION HAZARDS

 - 13 Steep slope prone to rock fall, debris flow and landslides
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 - 16 Debris flow
 - 17 Roadcut

HYDROLOGICAL HAZARDS

 - 18 Incision and aggradation of sediments**

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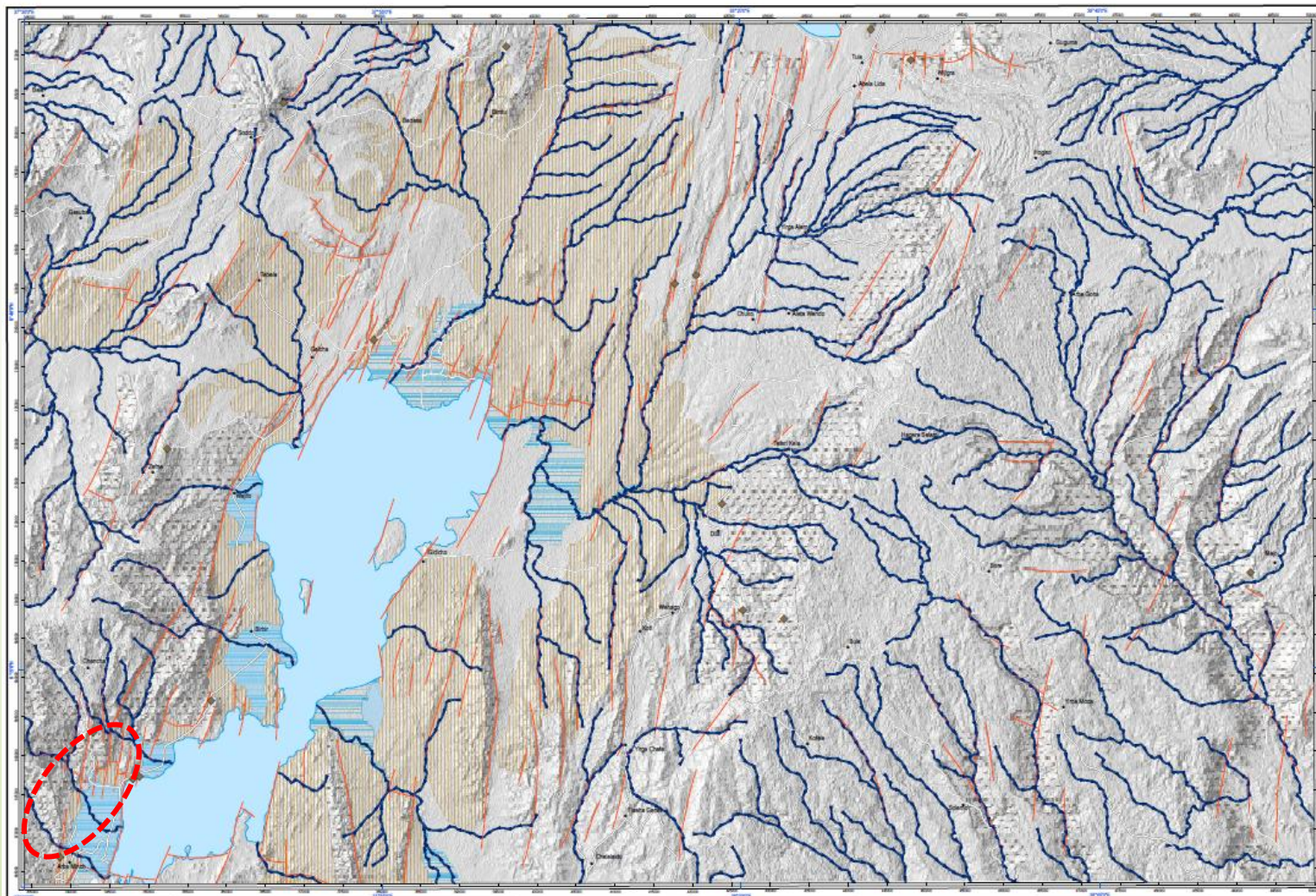
Coordinate system:
 Blue reference: WGS84 UTM
 Black reference: Adairson UTM, zone 37 N
 Projection: Transverse Mercator
 Ellipsoid: Spheroid 1986, Adairson



GEOHAZARD MAP OF DILA NB 37-6

Editor: V. Rappich

Sheet NB 37-6 Dila



MAP SHEET INDEX

1:250,000



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- ENDOGENOUS GEOHAZARDS**
- VOLCANIC HAZARDS**
- 1 Area with presence of volcanically monogenic volcanoes, where locally eruptions are expected during eruption more than 30 cm of pyroclastic material
 - 2 Volcanic ventral dikes
 - 3 Volcanic ventral dikes
- SEISMIC HAZARDS**
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Digital cartography: J. Rappich, J. Rappich



Coordinate system:
Blue horizontal: UTM zone 37N
Blue vertical: UTM zone 37N
Projection: Transverse Mercator
Datum: Czech 1989 datum



**THANK YOU FOR ATTENTION
DISCUSION**

