GEOSPATIAL -2013

PAPER NO. 60

Study of Physical Volcanological Features in the Pahoehoe Flow Exposed SE of Pune City Using Digital Image Analysis to understand stability of slopes

Rahul Joshi* , L. K. Kshirsagar P. B. Jadhav,

Research Centre in Geology,

MAEER's Maharashtra Institute of Technology

Pune-411038 (India)

*Corresponding Author: rahul.joshi@mitpune.edu.in

1. OBJECTIVE
2. SCOPE OF WORK
3. LOCATION AND ACCESS TO THE AREA
4. TOPOGRAPHY AND DRAINAGE
5. GEOLOGY OF THE AREA
6. METHODOLOGY AND OBSERVATIONS
   a. FIELD OBSERVATIONS
   b. APPLICATION OF ENGINEERING ROCK MASS CLASSIFICATION SCHEMES TO BASALT
7. CONCLUSIONS
8. REFERENCES

Objectives

❖Study of Physical Volcanological Features and their influence in the Pahoehoe Flow using Digital Imaging Technique

❖Measure and plot discontinuities in basalt and derive guidelines for stability of slopes for the region

❖To identify the most significant parameter influencing the engineering behaviour of basalt

❖Application of Engineering rock mass classification schemes to varieties of basalt based on Physical Volcanological Features

❖To understand rock failure / sliding mechanism for Pahoehoe flows of basalt

Methodology

- Lithologcal description of basalt was based on nomenclature system developed by Macdonald(1952), Walker (1971), and Bondre (2004)
- For defining flow units and related terminology field report of Geological Survey of India (1971)was used
- High resolution oriented photographs were taken in the field
- Mapping of various units of flow s were carried using the high resolution photographs
- Engineering Description of rock mass was carried out by using IS 11315(Part I to XII).
- Various Rock mass characterization methods such as Geological Strength Index, RMR ,were applied to understand engineering behaviour of the rock in field

Location and access to Dive ghat area

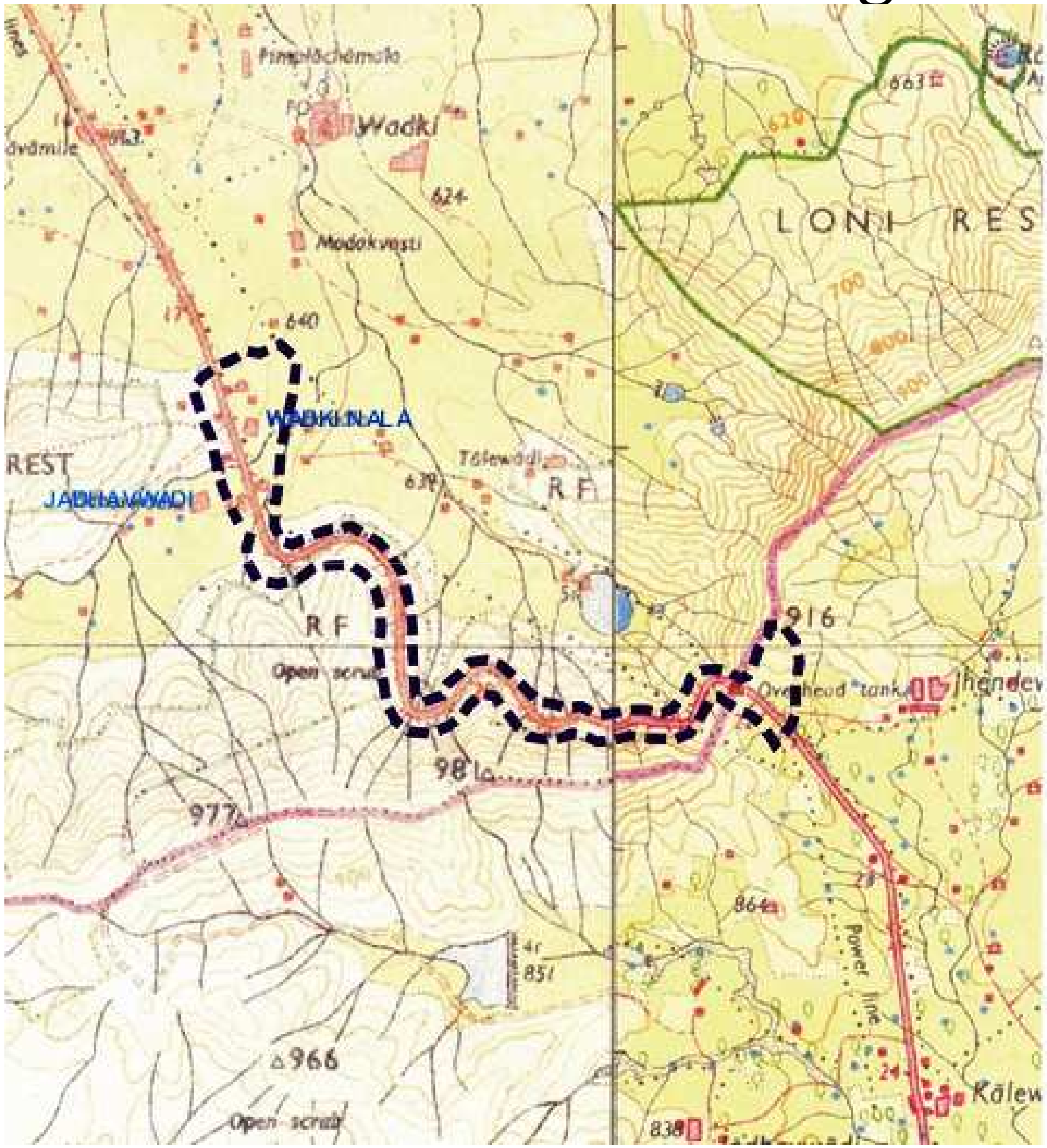
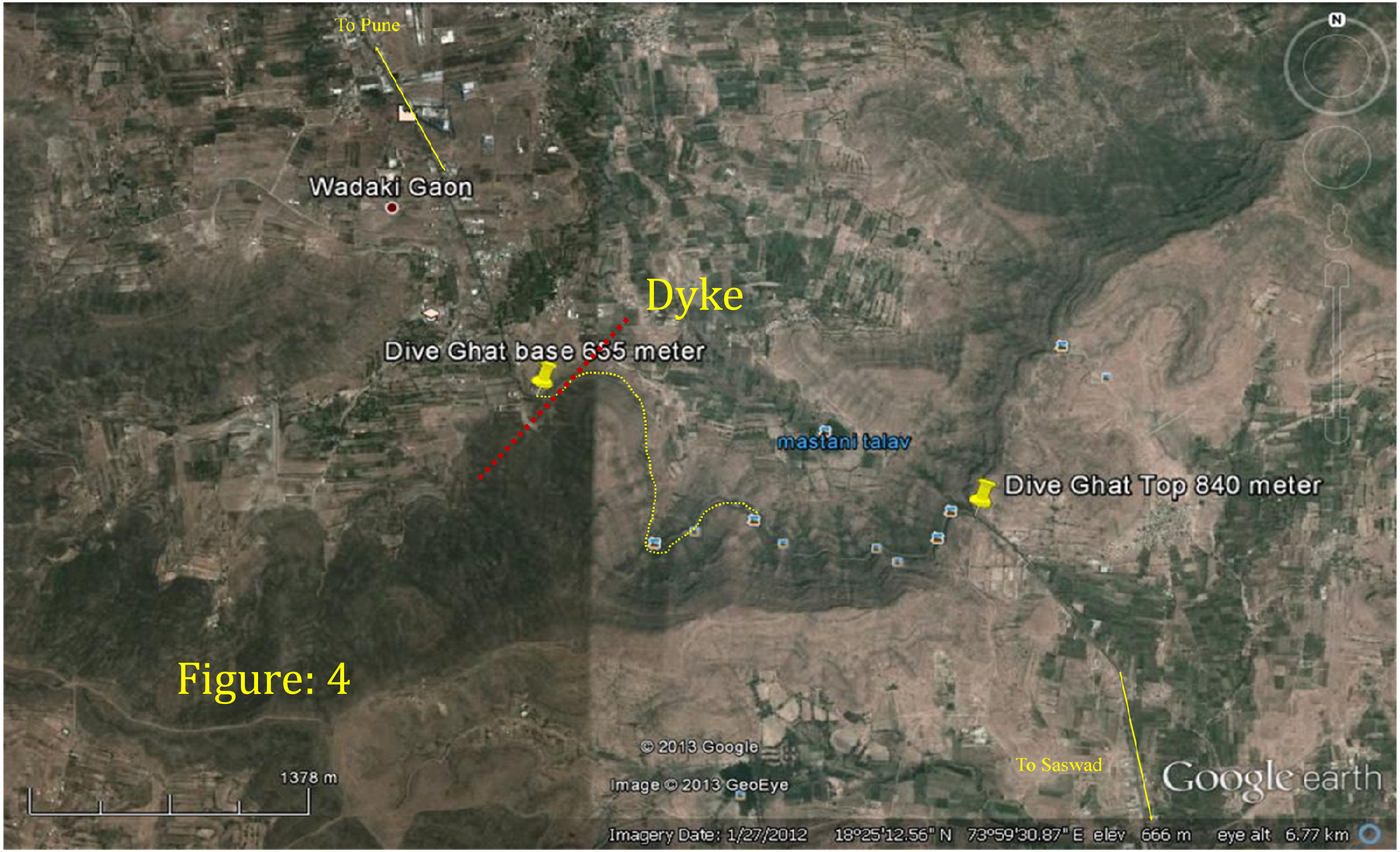


Figure: 1(Part of the Toposheet)

Location and access to Dive ghat area



Map showing the extent of the Deccan Volcanic Province (DVP) in India.

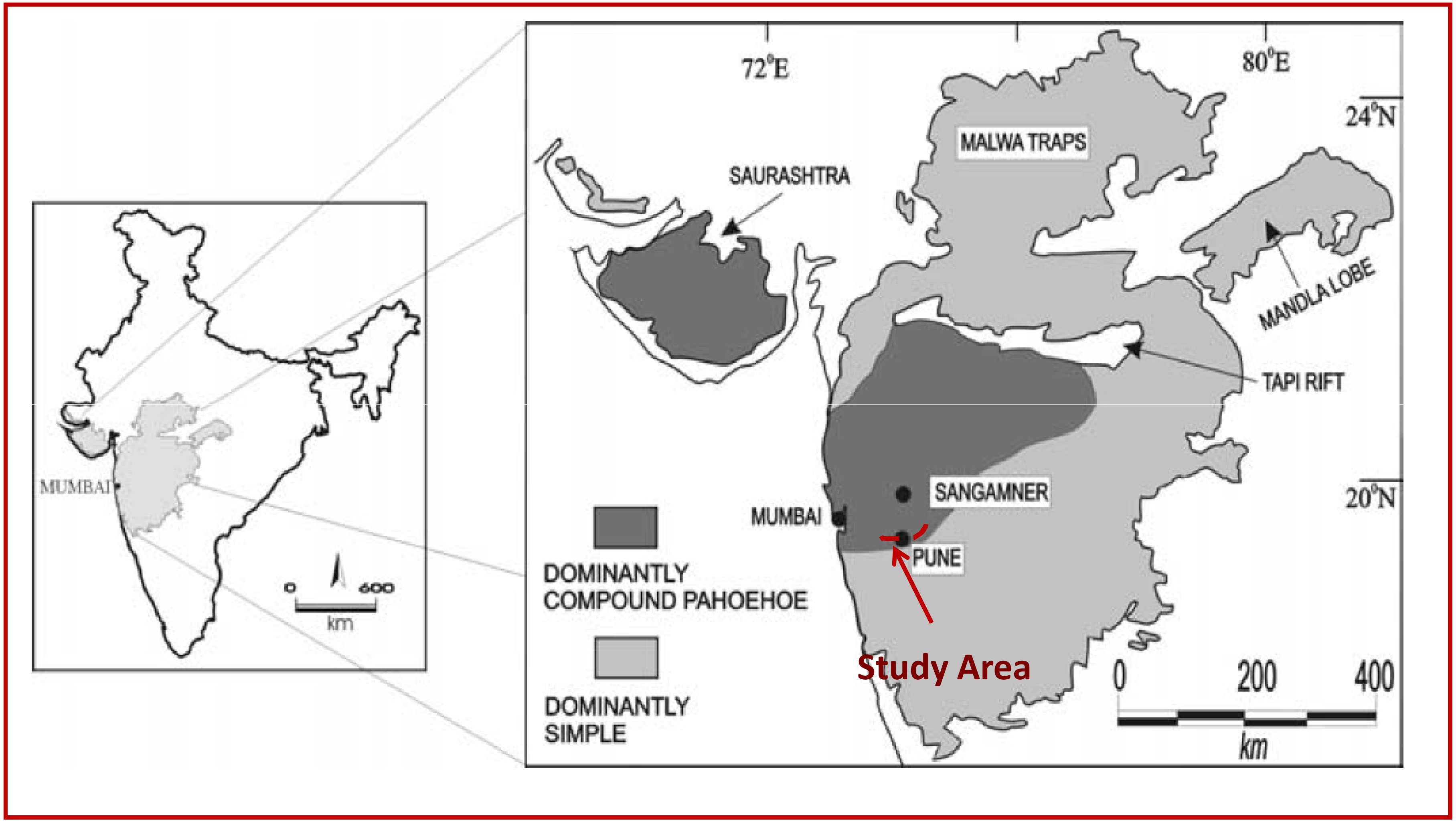


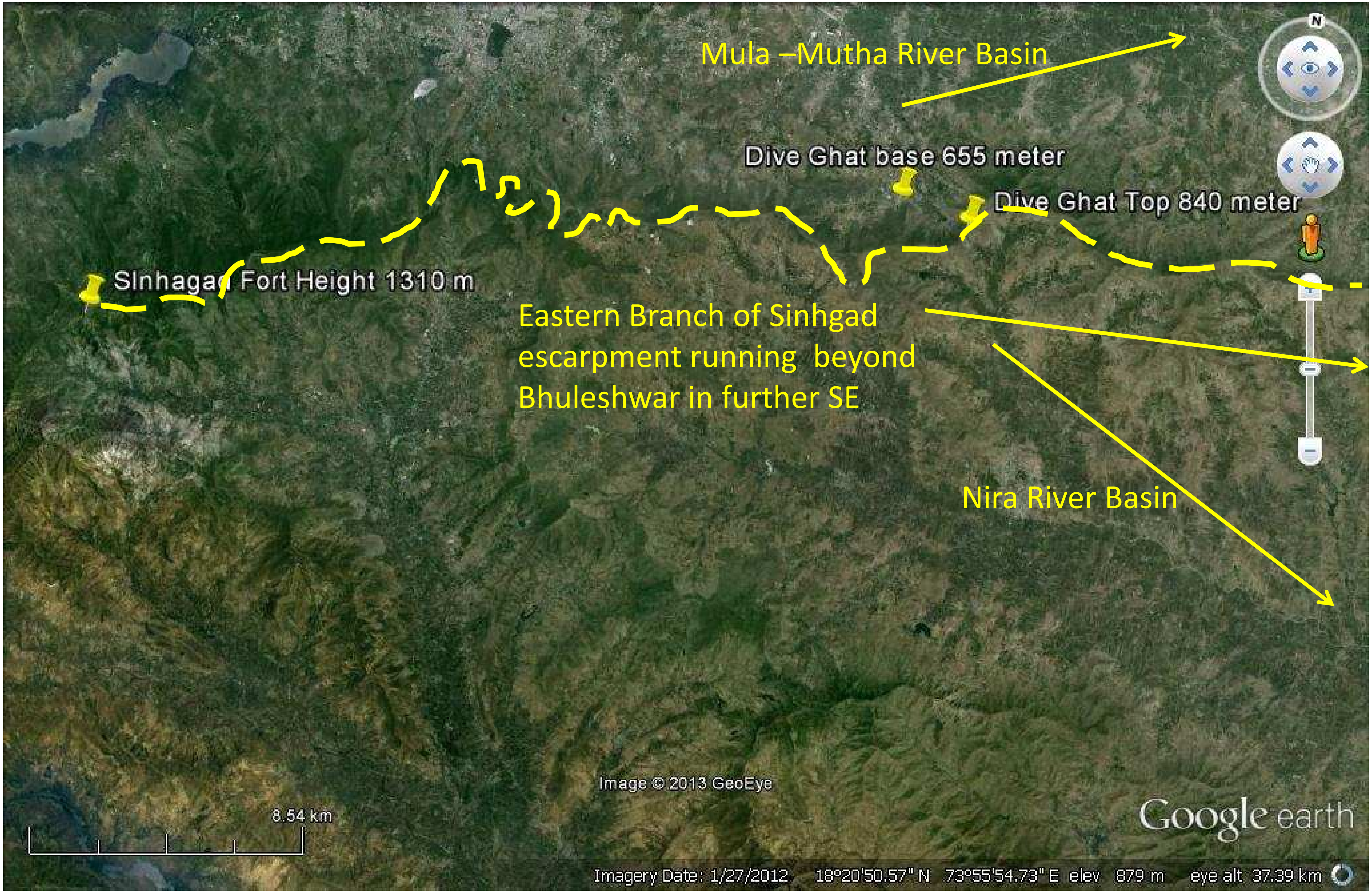
Figure: 2: The distribution of compound pahoehoe and simple flows (DVP) (Bondre et.al. 2004)

Lithostratigraphy of Deccan Basalt Volcanic Province (Godbole et al 1996)

Group	Subgroup	Formation	Thickness (m)
Sahyadri	-	Mahabaleshwar	600
	Wai	Purandargad	900
		Diveghat	
	Lonavala	Karla	700
		Indrayani	
		Ratangad	
	Kalsubai	Salher	Approx. 1500

Table: 01

Topography and Drainage



General Lithological Section Exposed in Dive Ghat

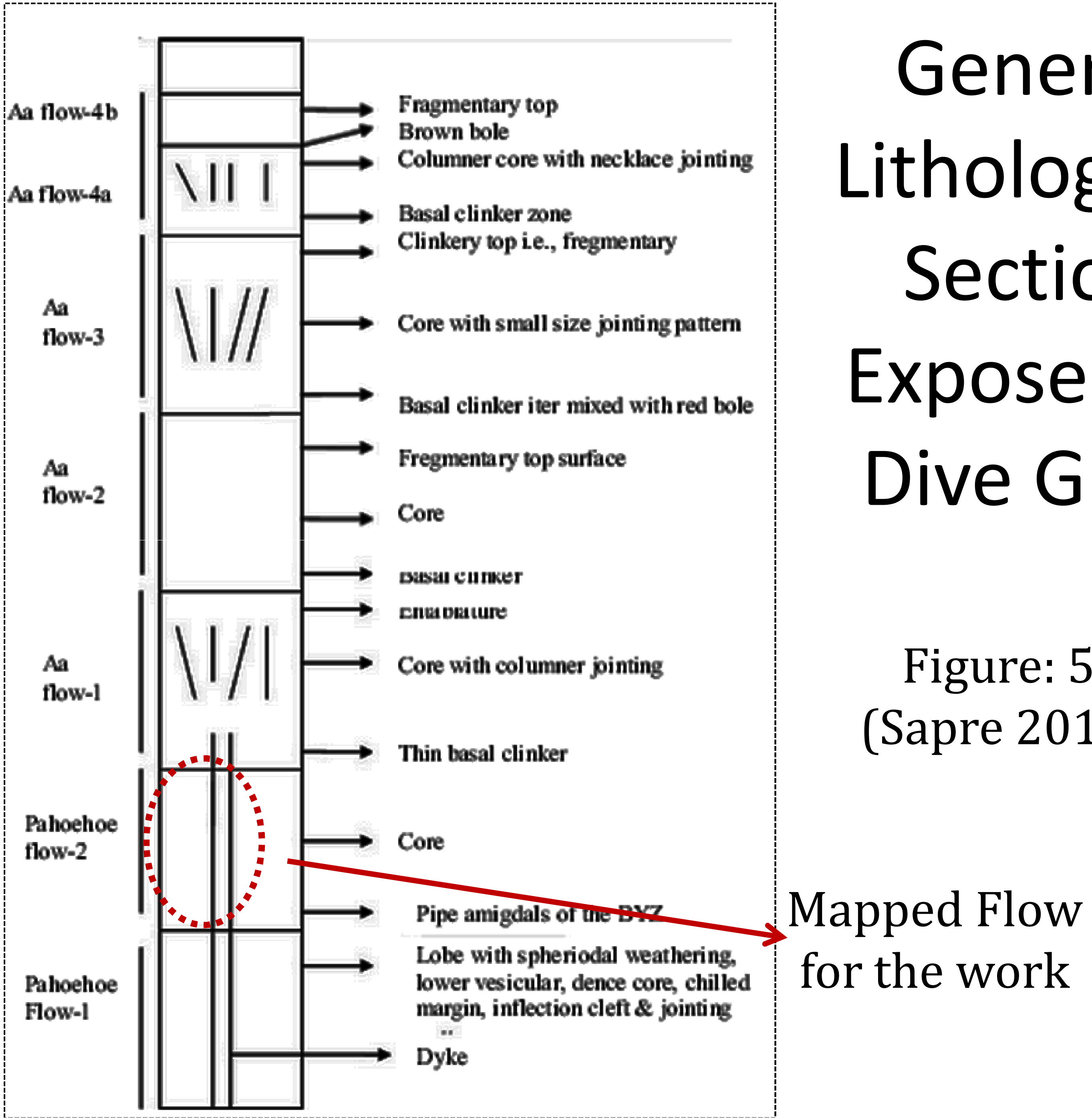


Figure: 5
(Sapre 2011)

Regional Geology of the area

According to Ghodke et al. (1970), the flows in this area are attributed to Diveghat formation forming part of upper Lonavala Subgroup of North Sahyadri group of Deccan Trap Supergroup (Figure:2).

The basalt pile exposed between 548 m and 724 m comprises several units of a compound pahoehoe flow, with the characteristic pipe amygdules at the base, massive middle section and the vesicular tops with a thin ropy crust.

Seven mappable horizons having lateral persistence can be delineated in this compound pahoehoe pile. Above this pahoehoe pile, are eleven aa flows.

Pahoehoe lava flow studied is designated as Flow group “G”

Minralogicaly these Basalts contain clinopyroxene, Ca-Na Plagioclase feldspar as the main constituent rock forming minerals.

Clinopyroxene, Ca-Na Plagioclase felspar are present as a groundmass and as a phenocrysts.

Zeolites and secondary silica occurs occupying vesicular cavities.

Formation of Pahoehoe Flow

- After Eruption development in the form of sheet lobes
- Development of various surface features on the top of the flow
- Development of various structural features within the flow during the phase of eruption

Constraints in Deccan Basalt

- Exposed basalt flows are relict of basalt flows erupted by the end of Cretaceous (~ 65 m.a.)
- Exposures are limited e.g. along road sections
- Part of flow is available for observation
- Most of the time the exposed parts are subjected to surface alteration, developing joints etc.
- Flows are subdivided into different flow units of unequal dimensions leading to difficulty in correlation of flow units / flows over a large area
- These factors pose a great challenge in ascertaining engineering behaviour of basalts

Growth stages of a pahoehoe sheet lobe at a fixed location

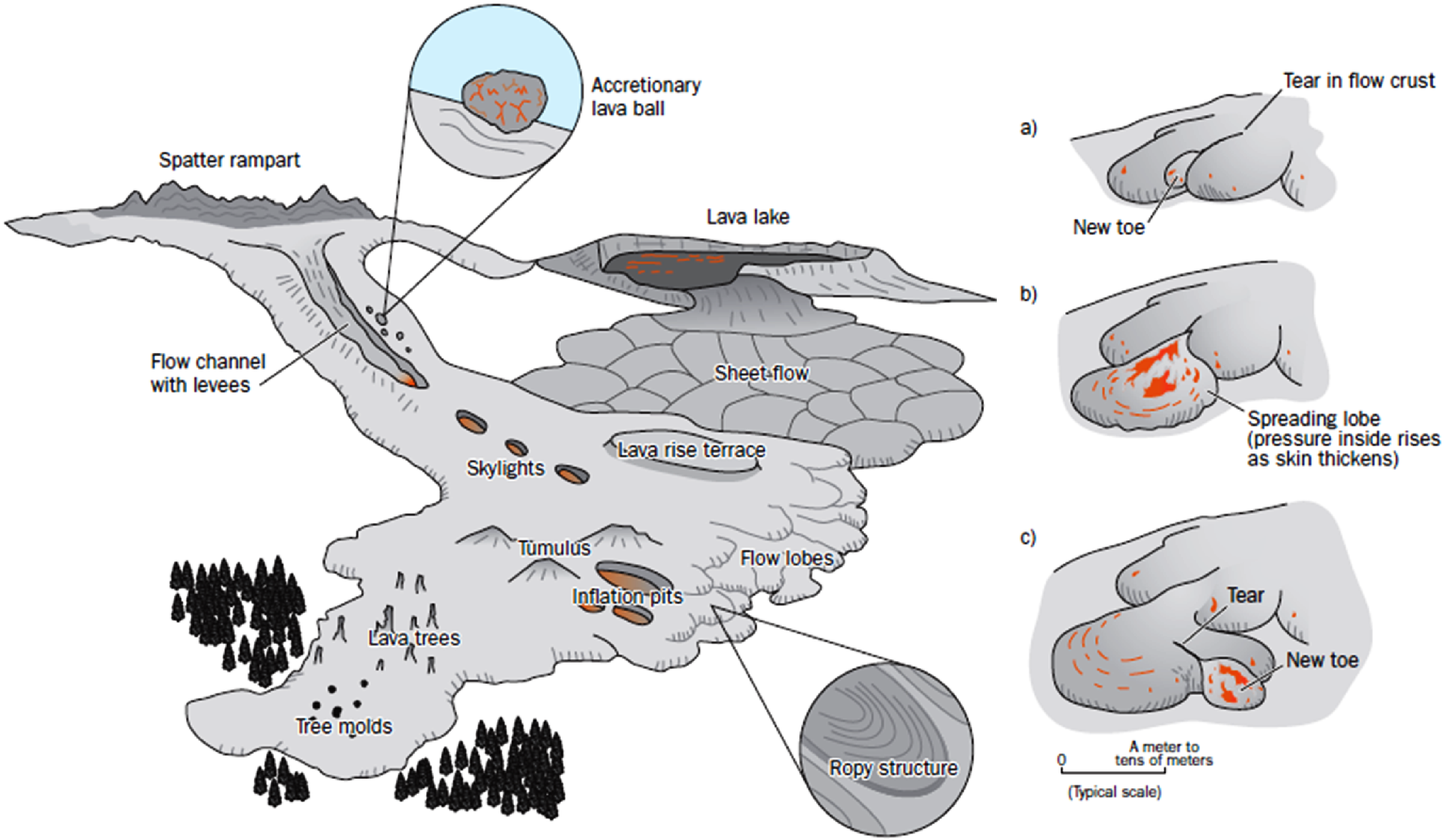


Figure : 6

Lockwood et.al. (2010)

Grape Bunch Analogy

Continuous pumping of liquid lava leading to inflation lobes of pahoehoe

In grapes stem acts as a feeder where as in pahoehoe individual lava lobe can act as a feeder and gives rise to new lobe/s

‘a‘ā	pāhoehoe
high vol. flow rate	low vol. flow rate
high flow-front velocity	low flow-front velocity
forms large channels	forms lava tubes
few, large flow units	innumerable flow units
thick flow units (2-10 m)	thin flow units (0.2-2 m)
higher viscosity	lower viscosity
slightly cooler	slightly hotter

Idealized cross section through an inflated pahoehoe lobe

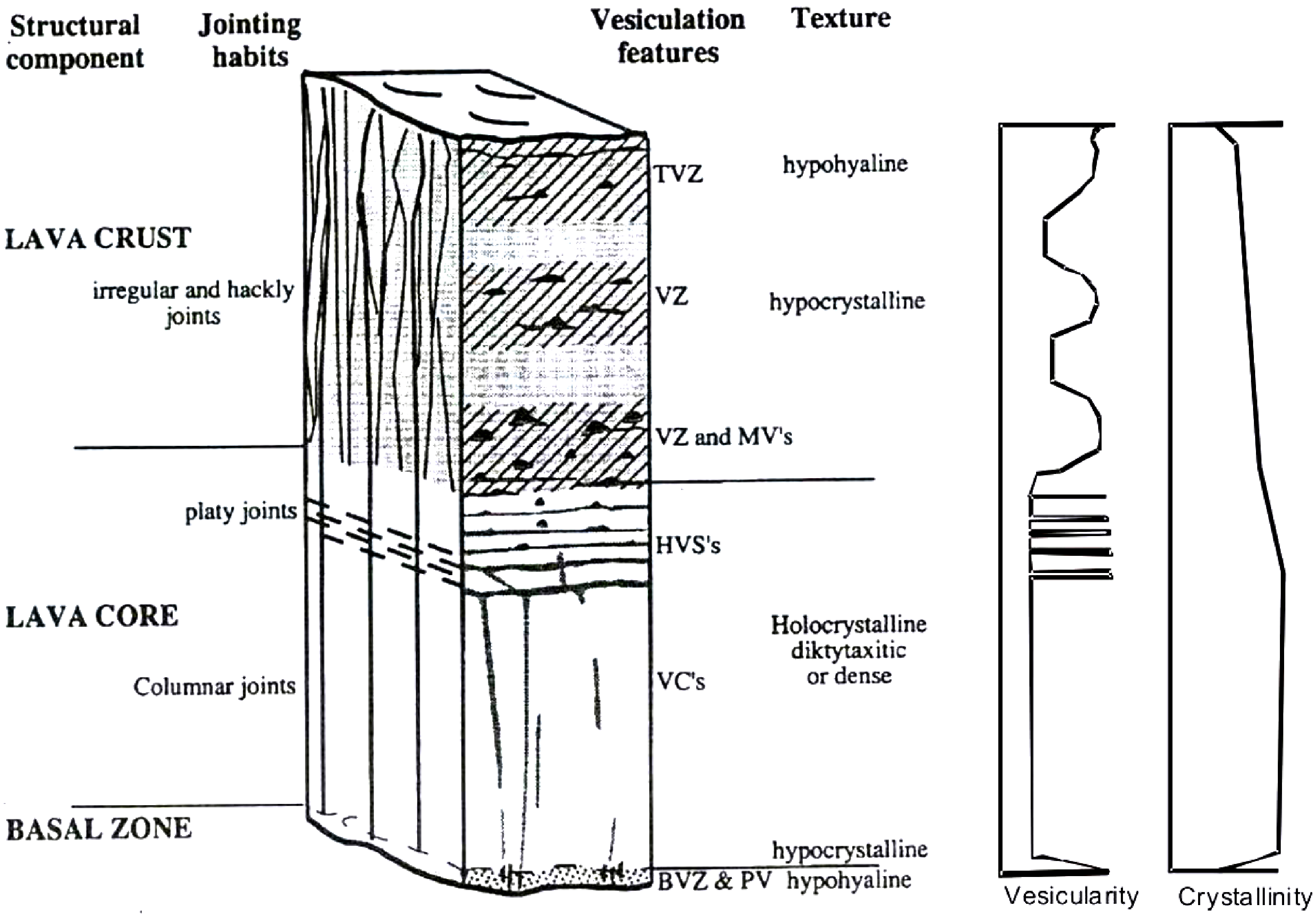


Figure : 8

Self et al, 1998

Physical Volcanological Features of Compound Pahoehoe Flows observed in the field

Megascopic characters

- Flow orientation,
- Secondary minerals,
- Vertical and lateral variations in megascopic characters like primary banding of minerals etc.
- Variation in Weathering characteristics within and around flow lobe /unit,

Volcanic characters

- Nature and density of vesicles,
- Coalescence of vesicles,
- Presence of vugs and cavities, their size, shape, whether filled and empty etc.
- Primary volcanic features like ropy structure, pipe amygdules
- Elongated vesicles, orientation of feldspars, ropy lava surface.

Physical Volcanological Features of Compound Pahoehoe Flows observed in the field

Structural details:

Nature of joints and their variation,
Direction of prominent sets of joints,
Dip of flows, fractures

Nature of lower and upper contacts of flows:

Chilled contact, fused contact, presence of glassy crust
Nature of marker horizon such as red bole, intertrappeans, ash or tuff beds, undulations in the contact and amplitude of undulations.

Thickness variation and lateral extent of flows:

Pinching of flows,
Direction of thickening of flows etc.,
Estimation of areal extent to study the geometry of flows.
Details of pyroclastic material found in basaltic areas
At times red bole may represent volcanic tuff or ash.

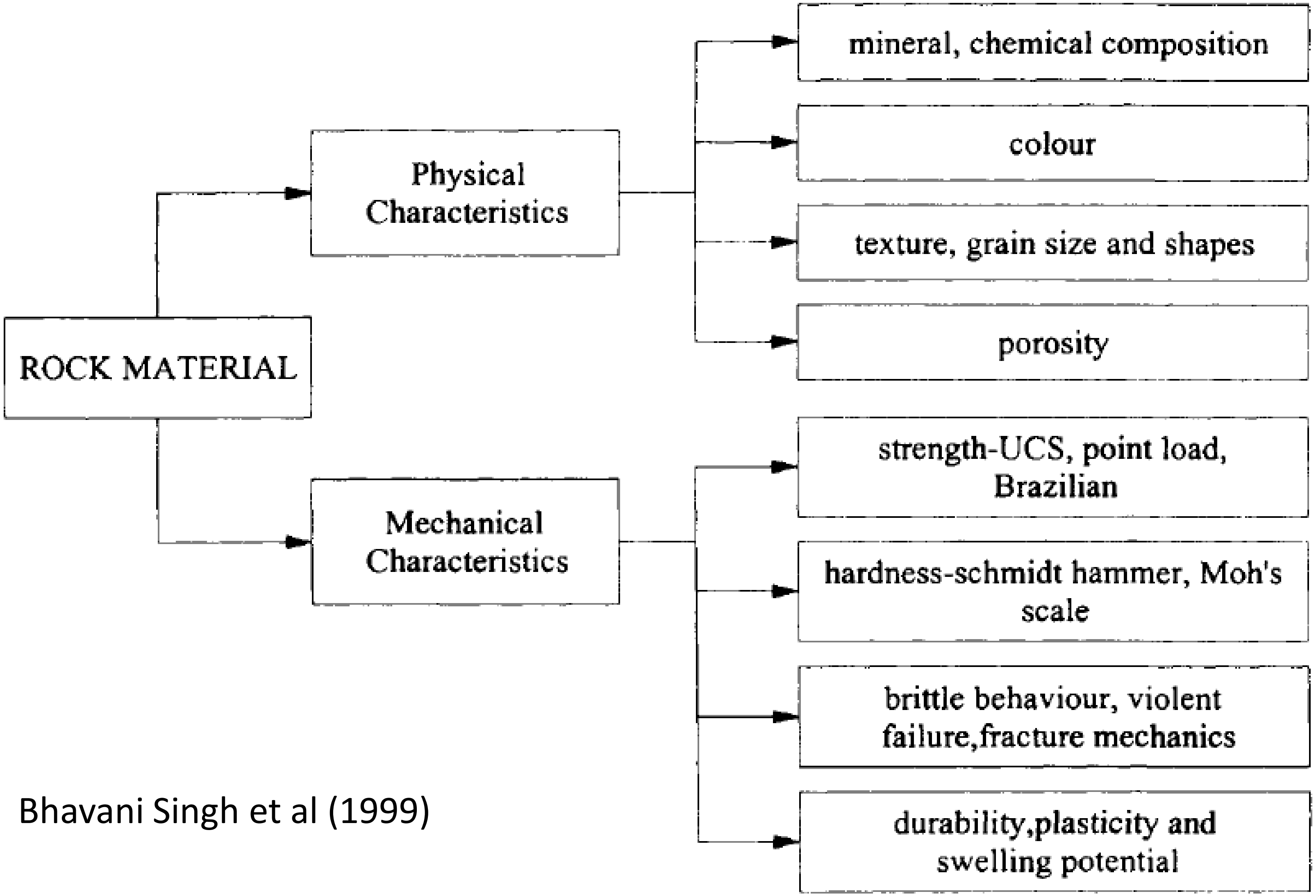
Observed Morphology of Pahoehoe Flows

- The compound pahoehoe flows are seen composed of a number of small toes or sheets and units measuring in thickness between 20 cm and 7 to 8 m. and extend laterally for a few meters.
- The larger flow units show up prominently and can be traced for tens of meters.
- The individual flow units have pipe amygdules at the base, a dense core and vesicular top with a glassy crust.
- A few of the units have a reddish crust and, at places, show ropy surface.
- The individual toes locally show gentle gradients
- The contacts between the pahoehoe flows show a 50 cm to a meter thick red bole at the contact.

Composite Lihtosection Exposed in Diveghat For Flow Group "G"

Flow Group and Thickness of the entire flow group measured m	R.L. in m	Chainage in km	Symbol	Thick. in m	Description as observed
Group G (3 units) Total Thickness = 36 m					
Lava Crust	727.4 m	19.175		0.30 to 0.45	Undulatory Interflow Red Horizon
				1.50	Platy Joint parallel to undulatory top, , amygdales 2-4 cm in size with 5-10 / 25 cm^2, oval, spherical shaped amygdales
		19.150		1.00	Top is reddish brown clefts(.30 m thick to few mm) filled with red bole, otherwise dense core
				1.00	Amygdular with 1-2 cm dia, oval shaped, 10 to 12 /25 cm^2,
		19.050		0.15 to 0.20	Spiracle, Reddish brown
Lava Core	716.9 m	19.000		1.50 to 1.70	Mega vesicle zone, at base pipe amygdales
		18.970		4.0	Reddish brown top with , amygdale size 1-2 cm, 10 to 12/25 cm^2, lower 2.0 m thick is zone of mega vesicles, with dia >4-5 cm , 2-4 /25 cm^2
		18.950	0 0 0 0 0 0 0 0	4.0	undulatory top with few mega vesicles, Curvilinear columnar joints with spacing 50-60 cm, oblique to each other, not forming a set, rest part of unit is dense core
		18.925		4.0	Top with thickness 5-7 cm, highly undulatory (1.5 m amplitude), with reddish brown crust , lower portion is amygdular with size 1-3 cm, oval, with no. 10-15 /25 cm^2
Basal Zone	698.9 m	18.910	00000000000000	3.0	Top is slight amygdular, with vesicle arranged parallel to top, otherwise dense core occasional vesicle cylinders,
		18.900	00000000000000 00000000000000	1.5	Closely spaced, weathered, platy joints high amygdularity observed along the unit,
		18.875		2.2	Dense core with curvilinear columnar joints, few joints are oblique and Zeolitized
	691.4m	18.875		0.60 to 1.00	Reddish Brown undulatory bottom with pipe amygdales 2-5 cm in length.

Characterization of Rock for Engineering Purpose



Bhavani Singh et al (1999)

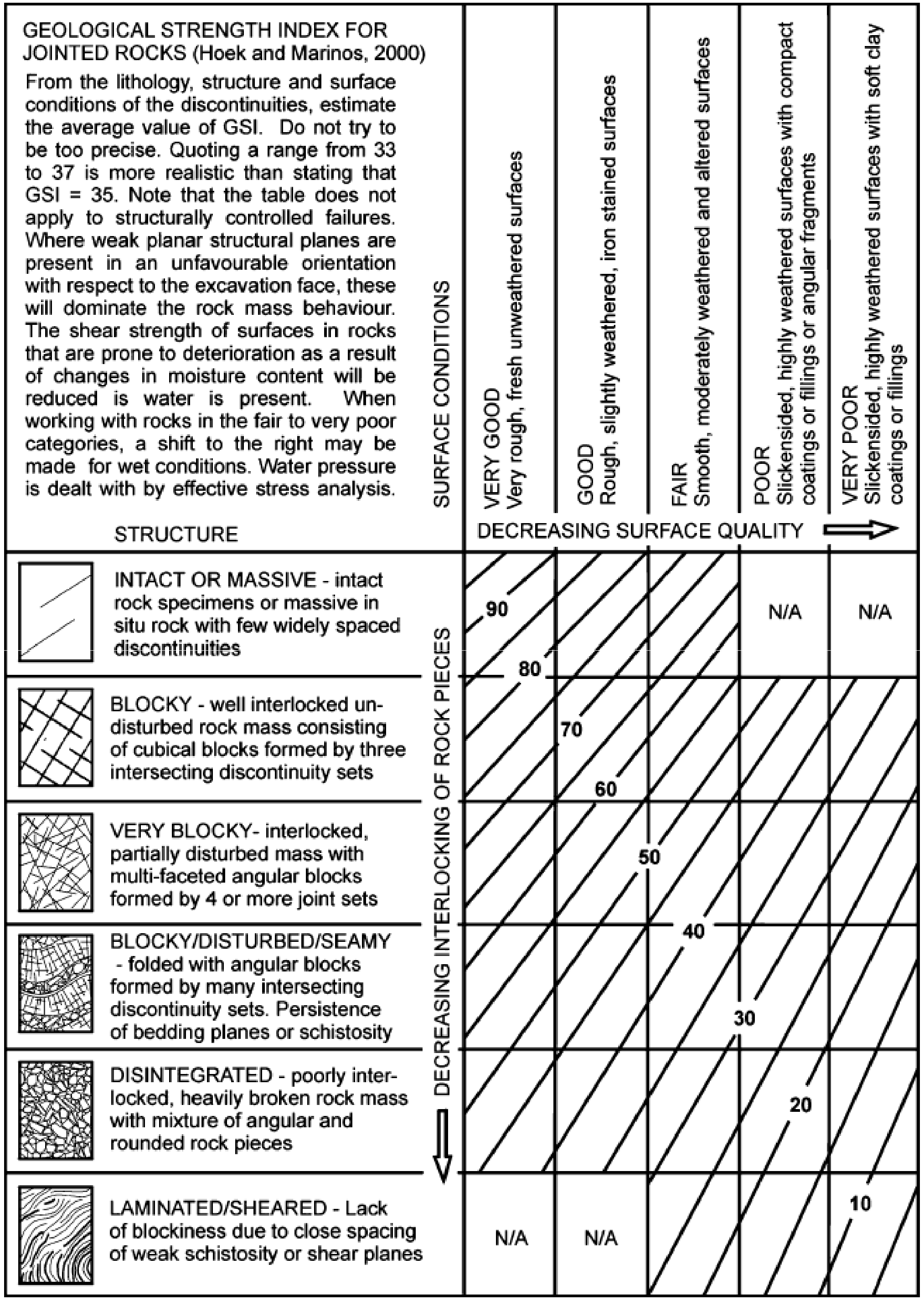


Chart for GSI estimates from the geological observations (1997, 2005)

INPUT DATA FORM : GEOMECHANICS CLASSIFICATION (ROCK MASS RATING SYSTEM)

Name of project:

Site of survey:

Conducted by:

Date:

STRUCTURAL REGION	DEPTH, m	ROCK TYPE

STRENGTH OF INTACT ROCK MATERIAL

Designation	Uniaxial compressive strength, MPa	OR	Point-load strength index, MPa
Very High:	Over 250		>10
High:	100-250		4-10
Medium High:	50-100		0-4
Moderate:	25-50		1-2
Low:	5-25		<1
Very Low:	1-5		

DRILL CORE QUALITY R.Q.D.

Excellent quality:	90-100%	....
Good quality:	75-90%	....
Fair quality:	50-75%	....
Poor quality:	25-50%	....
Very poor quality:	<25%	....

R.Q.D. = Rock Quality Designation

STRIKE AND DIP ORIENTATIONS

Set 1 Strike............ (average) (from .... to ....) Dip:............ (angle) .... (direction)

Set 2 Strike............ (from .... to ....) Dip:............ ....

Set 3 Strike............ (from .... to ....) Dip:............ ....

Set 4 Strike............ (from .... to ....) Dip:............ ....

NOTE: Refer all directions to magnetic north.

SPACING OF DISCONTINUITIES

		Set 1	Set 2	Set 3	Set 4
Very wide:	Over 2 m	....	....	....	....
Wide	0.6 - 2 m	....	....	....	....
Moderate:	200 - 600 mm	....	....	....	....
Close:	60 - 200 mm	....	....	....	....
Very close:	< 60 mm	....	....	....	....

GROUND WATER

INFLOW per 10 m of tunnel length liters/minute ....

or

WATER PRESSURE kPa ....

GENERAL CONDITIONS (completely dry, damp, wet, dripping or flowing under low/medium or high pressure): ....

IN SITU STRESSES

CONDITION OF DISCONTINUITIES

PERSISTENCE (CONTINUITY)		Set 1	Set 2	Set 3	Set 4
Very low:	< 1 m	....	....	....	....
Low:	1 - 3 m	....	....	....	....
Medium:	3 - 10 m	....	....	....	....
High:	10 - 20 m	....	....	....	....
Very high:	> 20 m	....	....	....	....
SEPARATION (APERTURE)					
Very tight joints:	< 0.1 mm	....	....	....	....
Tight joints:	0.1 - 0.5 mm	....	....	....	....
Moderately open joints:	0.5 - 2.5 mm	....	....	....	....
Open joints:	2.5 - 10 mm	....	....	....	....
Very wide aperture:	> 10 mm	....	....	....	....
ROUGHNESS (state also if surfaces are stepped, undulating or planar)					
Very rough surfaces:		....	....	....	....
Rough surfaces:		....	....	....	....
Slightly rough surfaces:		....	....	....	....
Smooth surfaces:		....	....	....	....
Slickensided surfaces:		....	....	....	....
FILLING (GOUGE)					
Type:		....	....	....	....
Thickness:		....	....	....	....
Uniaxial compressive strength, MPa		....	....	....	....
Seepage:		....	....	....	....
WALL ROCK OF DISCONTINUITIES					
Unweathered		....	....	....	....
Slightly weathered		....	....	....	....
Moderately weathered		....	....	....	....
Highly weathered		....	....	....	....
Completely weathered		....	....	....	....
Residual soil		....	....	....	....

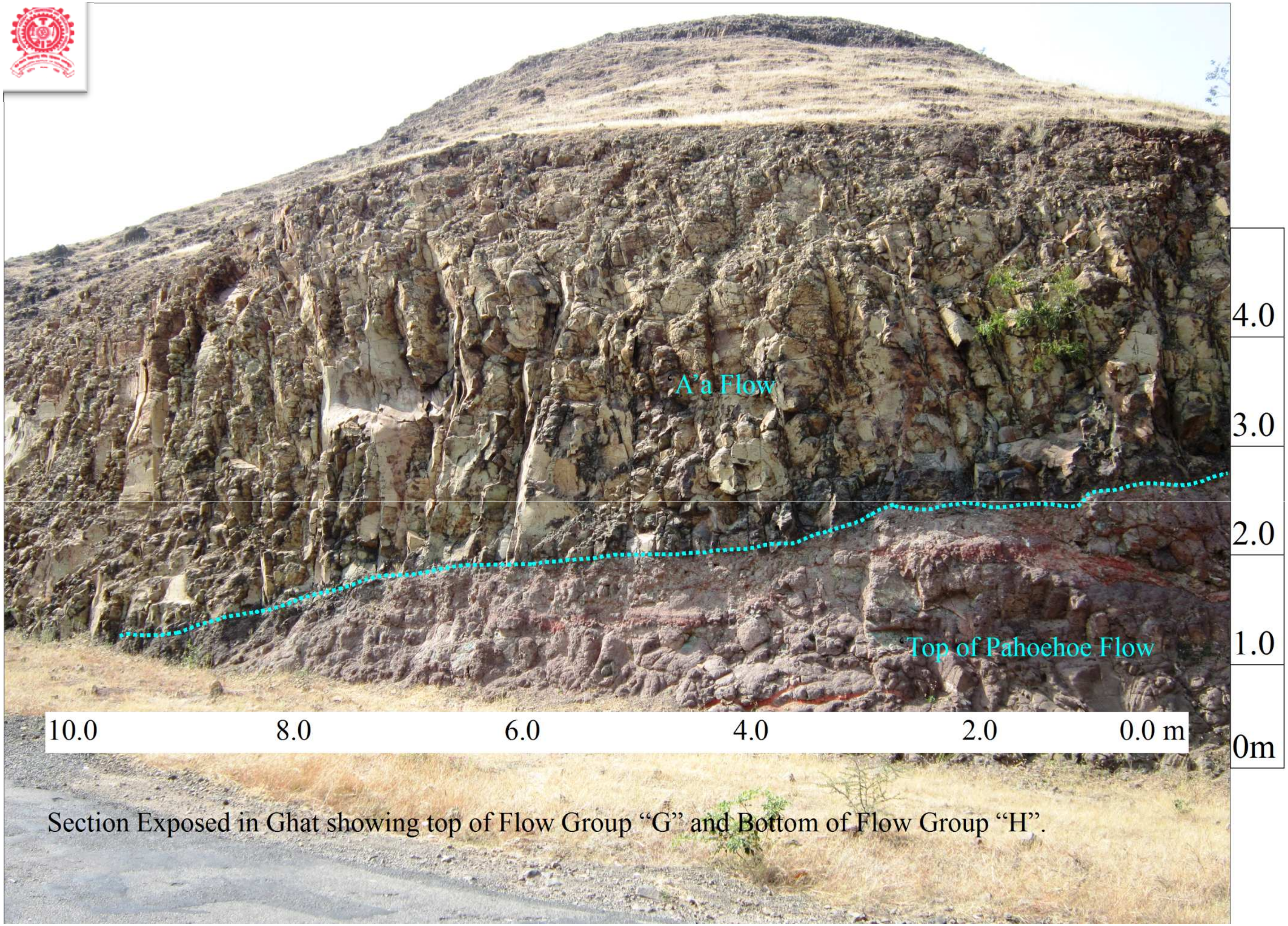
GENERAL REMARKS AND ADDITIONAL DATA

MAJOR FAULTS specify locality, nature and orientations.

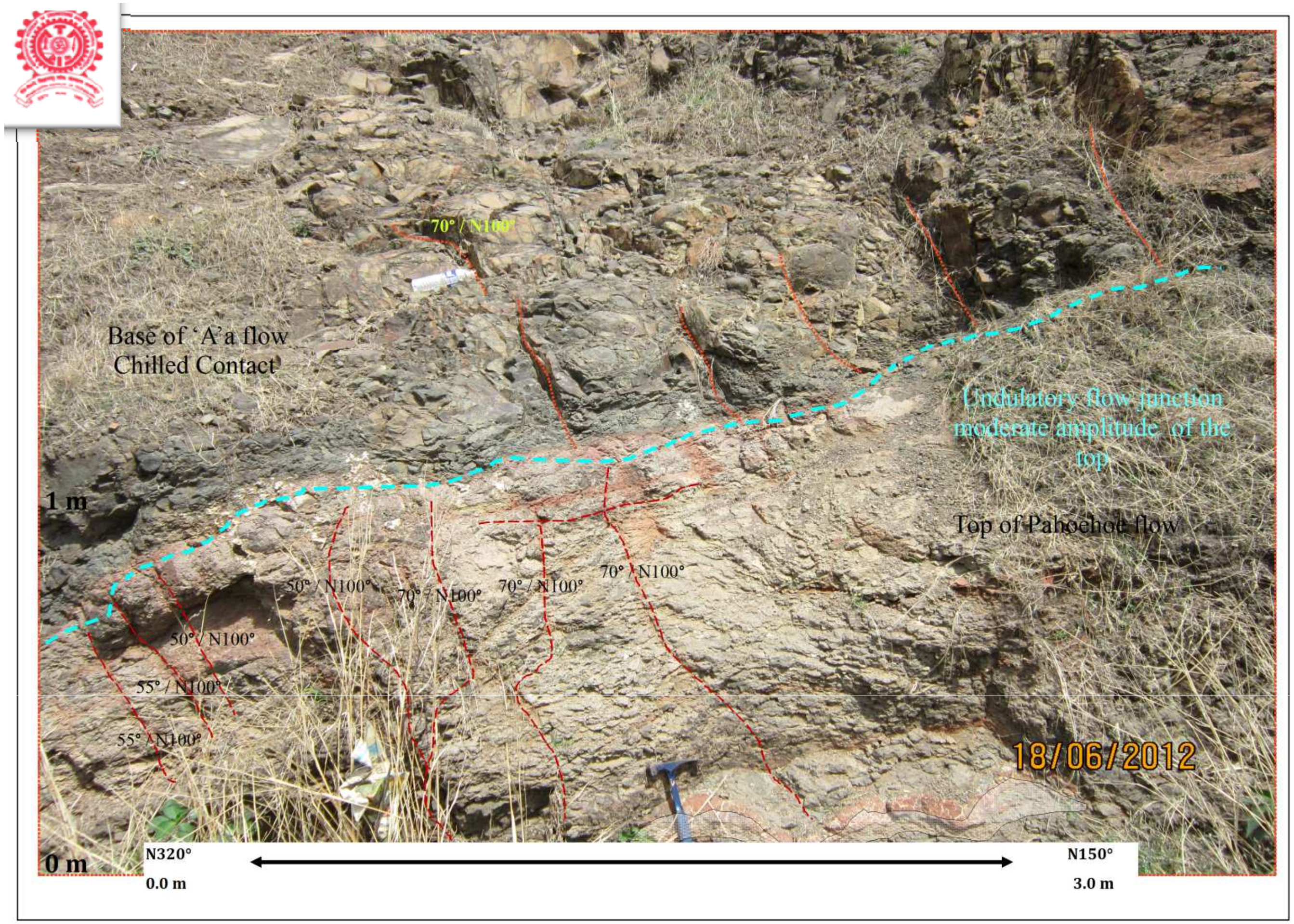
NOTE: For definitions and methods consult ISRM document: *'Quantitative description of discontinuities in rock masses.'*

WHY Digital Image Analysis, DIA?

- DIA allows precise mapping of features difficult to observe and resolve in the field. e.g. vesiculation, banding of vesicles, spiracles of various sizes can be worked out
- Relationship between discontinuities and their effects leading to weathering, failure and sliding can be precisely mapped using DIA.
- Interrelation of various component of flow units is easily recognizable using high resolution digital images
- Handy tool to deduce engineering parameters of rock mass



Section Exposed in Ghat showing top of Flow Group "G" and Bottom of Flow Group "H".

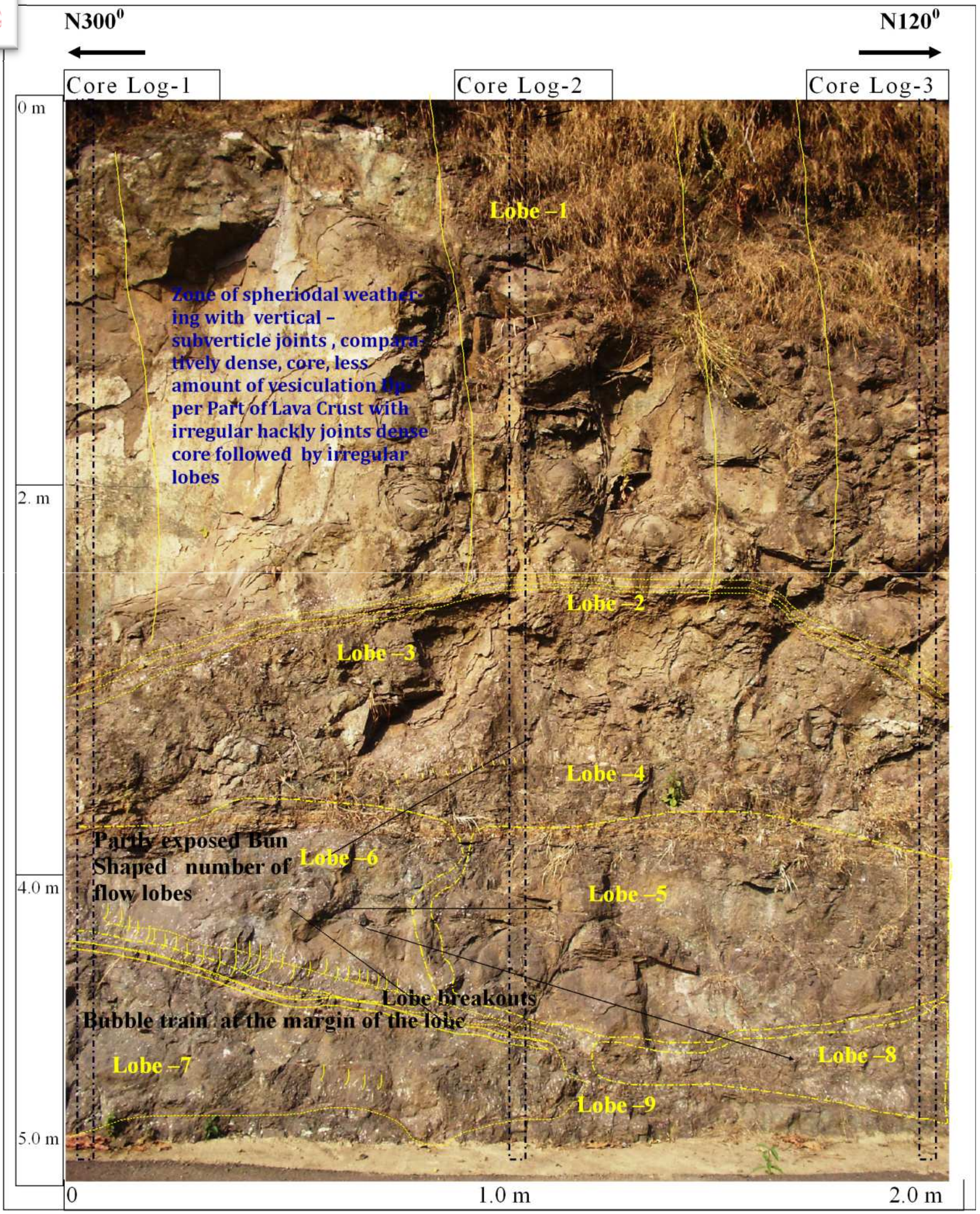


Separation of Overlying flow group “H” and Flow group “G’

Top of Lava Crust of Flow Group “G” exposed at Chainage 19.175 km

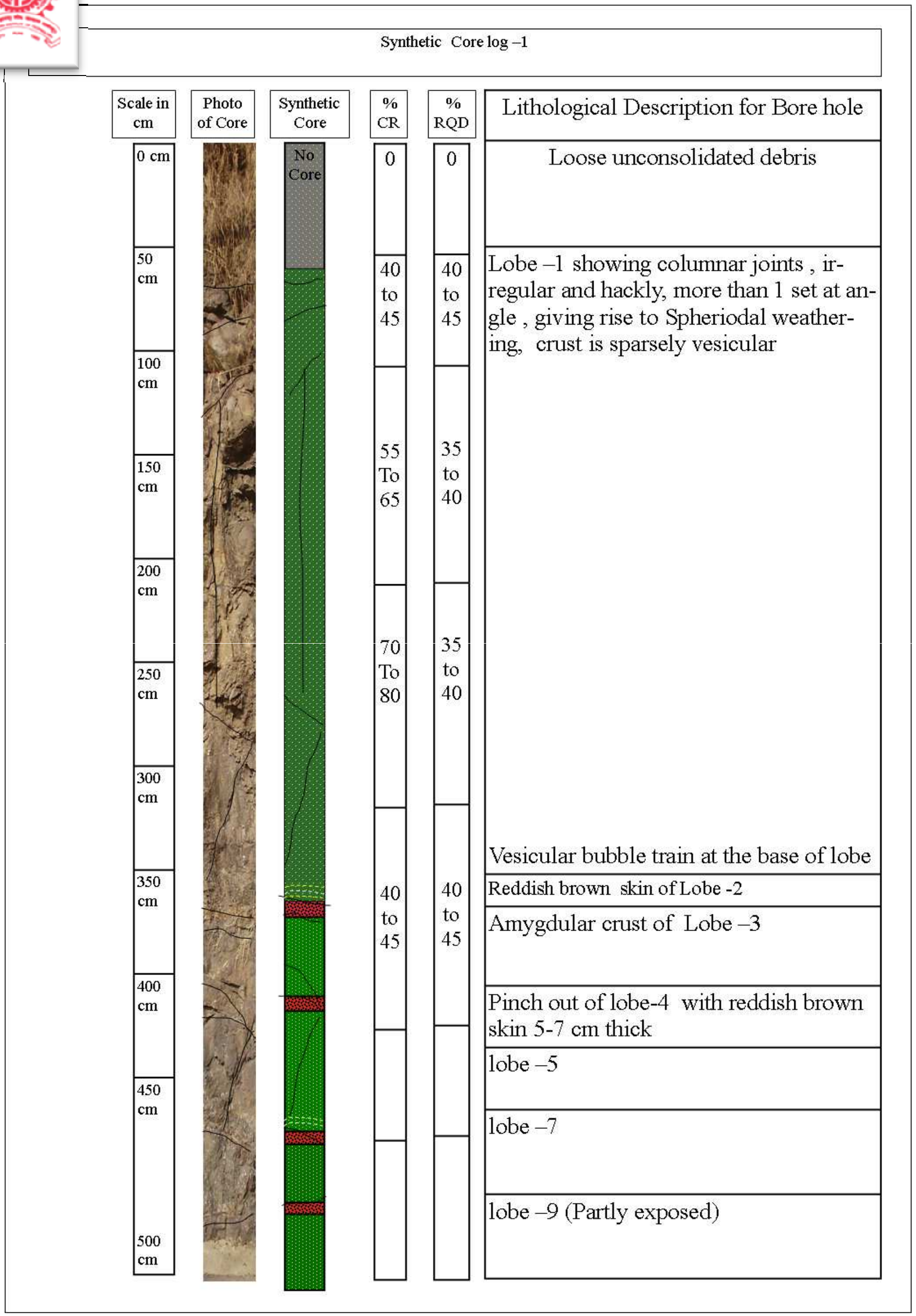
Separation between overlying dense flow group “H” and lower “G” is done on the basis of color, vesicles, discontinuity related parameters of is prominently studied using DIA

Thin reddish brown crust underlain by grayish brown amygdular basalt is seen in the lower part of the photo.



Typical bun shaped flow morphology of pahoehoe exposed in the ghat section

- More than 9 lobes, one dense core zone can be identified using the DIA.
- Decomposition of Margins of lobes observed due to discoloration
- Separation between overlying dense core and lower lobes is prominently studied using DIA

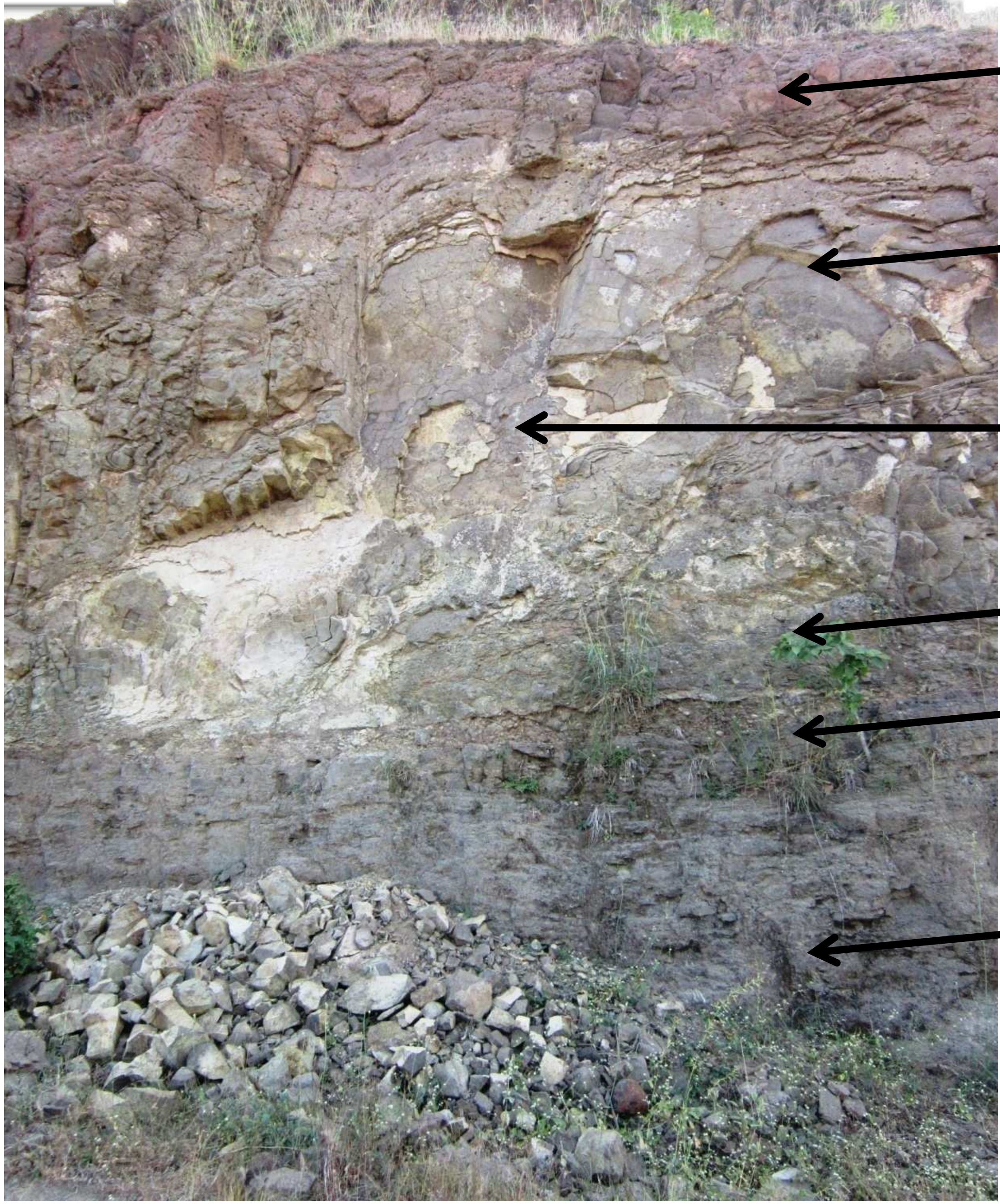


Evaluation of Engineering Parameters for the exposed section

- Decomposition category of rock at various levels
- Discontinuity parameters
  - Persistence
  - Set
  - Aperture
  - Seepage
  - Weathering

This heterogeneity leads to unrealistic evaluation of RQD by existing method

Flow Morphology for G



Lava Crust
Reddish Brown Top at places fragmentary,

Highly weathered zone separating upper flow lobes and lower dense core portion

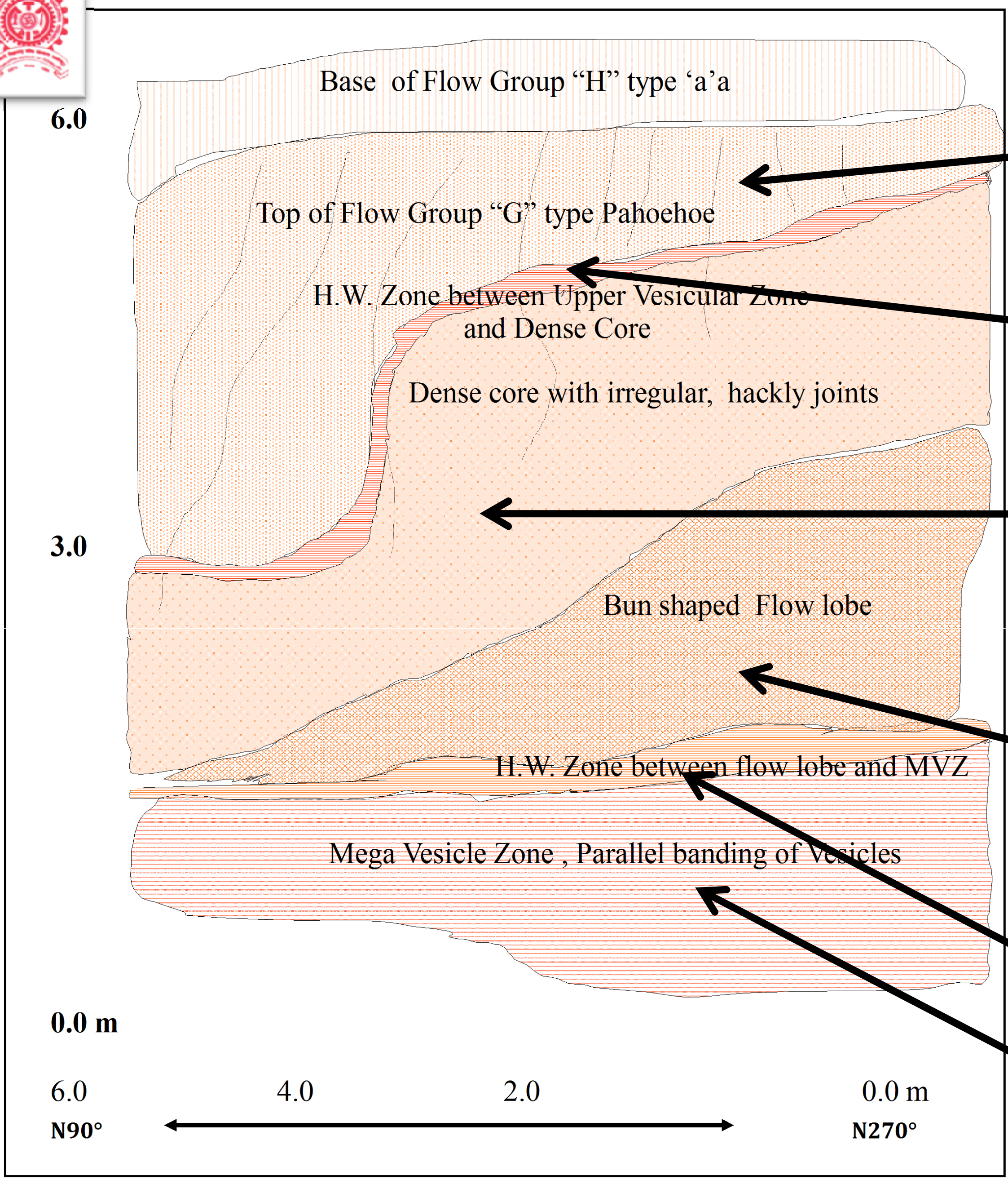
Dense Core , Very low vesiculation, secondary zeolitization

Flow lobe with irregular and decomposed margin

Highly weathered zone separating upper dense core and lower band of vesicles

Vesicular banding with more than 5-6 layers of vesicles of different sizes.

Mapped Flow Morphology for G using DIA



Irregular Hackly joints, WI=II-III along joints, tight aperture, no flow or seepages, , less persistent, GSI= 55-60, RMR= 45-50

Closely to very closely spaced joints, deeply decomposed, water seepage, GSI= 20-25, RMR= 25-30

Secondary zeolitization along joints, with WI=I-II, persistent Joints, no seepage, tight with aperture1-3 mm,
GSI= 55-60, RMR= 55-60

WI of Margin IV to V, and interior with WI : I-II, GSI= 20-25, RMR= 25-30, Interior GSI= 60-65, RMR= 60-65

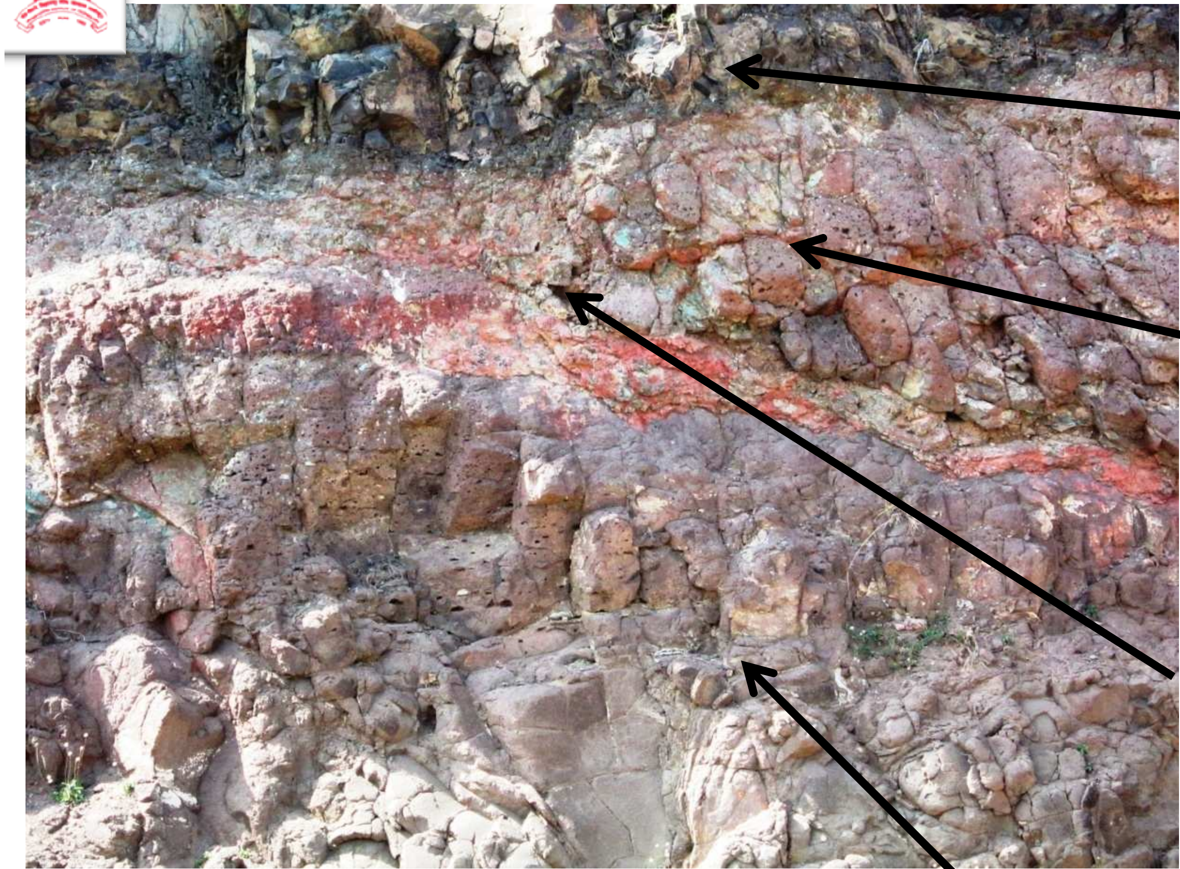
Closely to very closely spaced joints, deeply decomposed, water seepage, GSI= 20-25, RMR= 25-30

Closely spaced jointing , parallel to vesicle bands, GSI= 20-25, RMR= 25-30

Engineering Assessment of various units

Discontinuity parameters

Persistence



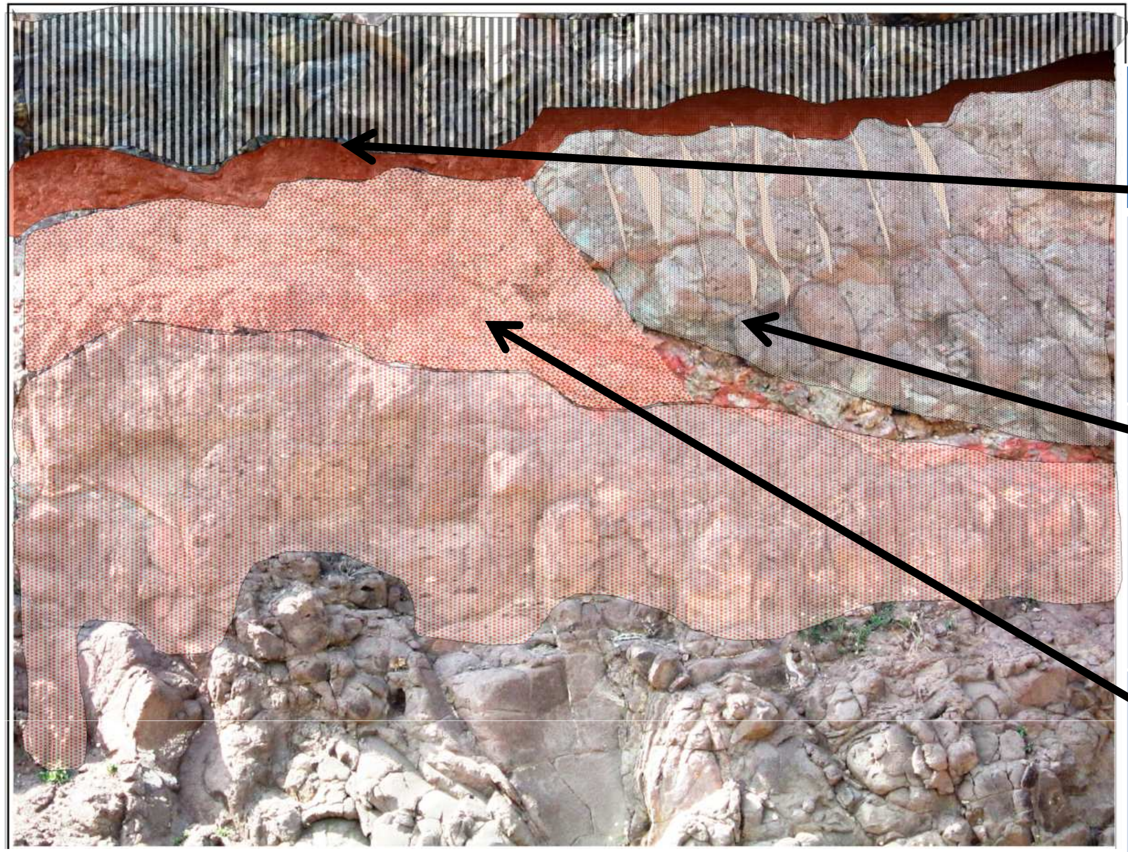
Flow Morphology for G

Lava Crust
Reddish Brown Top at places fragmentary, GSI= 20-25, RMR= 25-30

Closely spaced jointing, hackly to columnar, persistency within the lobe, aperture tight, GSI= 30-35, RMR= 25-30

Very high vesiculation, irregular margins to the adjacent lobes, Closely spaced jointing, hackly to columnar, persistency within the lobe, aperture tight,

Flow lobe with margin zeolitised



Mapped Flow Morphology for G using DIA

Lava Crust
Reddish Brown Top at places fragmentary, fresh, zeoitiesed,

Closely spaced jointing, hackly to columnar, persistency within the lobe, aperture tight, seepage not noticed,

Very high vesiculation, irregular margins to the adjacent lobes, Closely spaced jointing, hackly to columnar, persistency within the lobe, aperture tight,

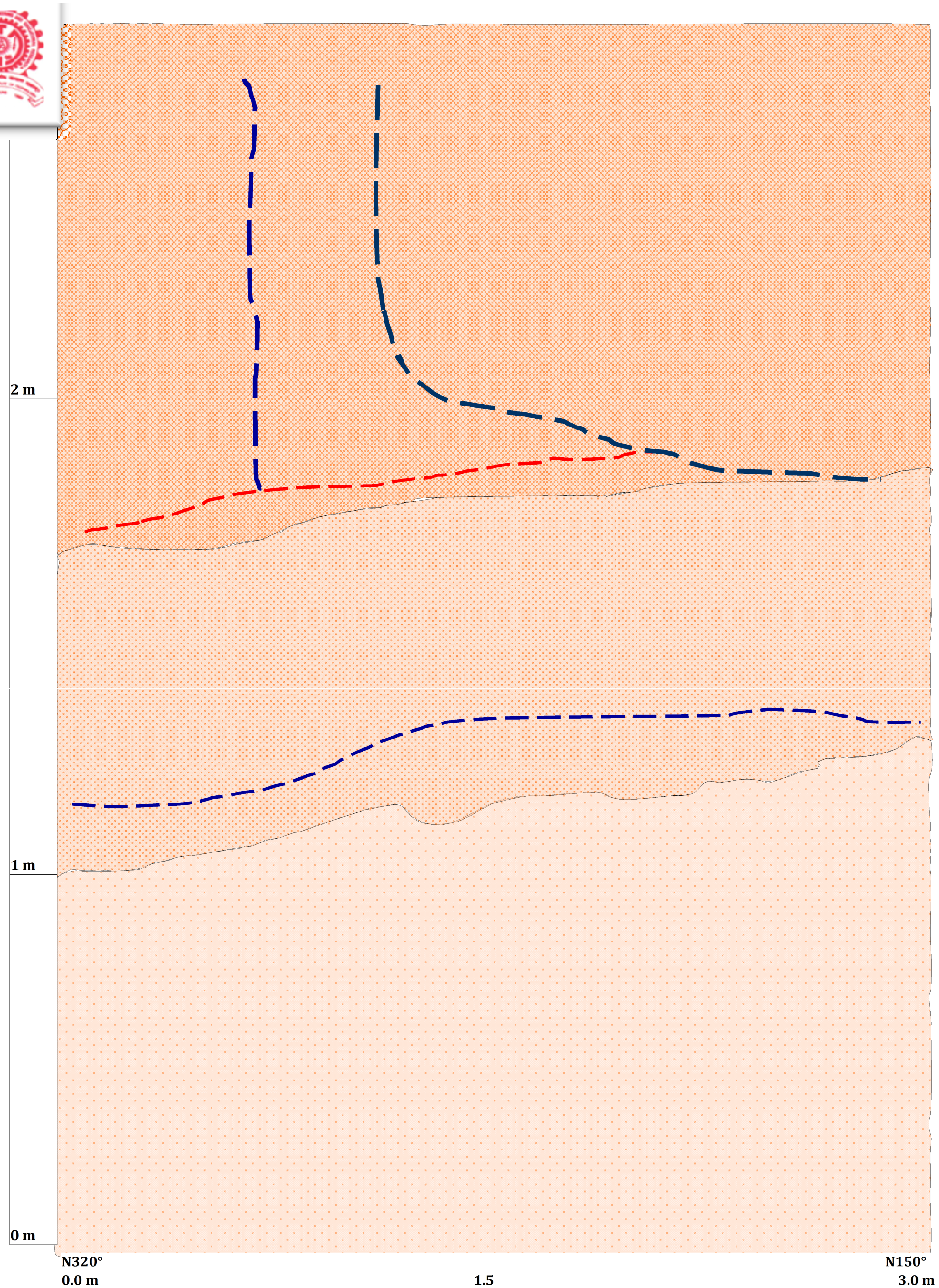
Flow Morphology for G

Decomposed to moderately weathered zone of vesiculation, amygdular, with impersistent joints

Closely to very closely spaced joints, deeply decomposed, water seepage,

Dense Core , Very low vesiculation, impersistent joints,

Mapped Flow Morphology for G using DIA



Decomposed to moderately weathered zone of vesiculation, amygdular, with impersistent joints, GSI: 30-35, RMR: 35

Closely to very closely spaced joints, deeply decomposed, water seepage, GSI: 30-35, RMR: 25-30

Dense Core , Very low vesiculation, impersistent joints, GSI: 75-80, RMR: 75

Conclusion

- Physical Volcanological features can be suitably delineated using the DIA technique

- Assessment of engineering parameters is much better using DIA

- This can be used as an additional tool in studying these features

References

1.Bieniawski Z.T. (1989): Engineering Rock mass Classifications, Wiley – Interscience , New York, pp: 1-251

2.Bhavani Singh, R.K. Goel (1999)"Rock Mass Classification A Practical Approach In Civil Engineering, ELSEVIER SCIENCE Ltd, UK, pp: 1-267

3.IS: 11315 (1987)"Method for quantitative description of discontinuities in rock masses, Part- 1, Orientation", Bureau of Indian Standards, pp 1-21.

4.IS: 11315 (1987)"Method for quantitative description of discontinuities in rock masses, Part- 2, Spacing", Bureau of Indian Standards, pp 1-9.

5.IS: 11315 (1987)"Method for quantitative description of discontinuities in rock masses, Part- 3, Persistence", Bureau of Indian Standards, pp 1-11.

6.IS: 11315 (1987)"Method for quantitative description of discontinuities in rock masses, Part- 4, Roughness", Bureau of Indian Standards, pp 1-20.

7.IS: 11315 (1987)"Method for quantitative description of discontinuities in rock masses, Part- 5, Wall strength", Bureau of Indian Standards, pp 1-13.

8.IS: 11315 (1987)"Method for quantitative description of discontinuities in rock masses, Part- 6, Aperture", Bureau of Indian Standards, pp 1-9.

9.IS: 11315 (1987)"Method for quantitative description of discontinuities in rock masses, Part- 7, Filling", Bureau of Indian Standards, pp 1-9.

10.IS: 11315 (1987)"Method for quantitative description of discontinuities in rock masses, Part- 8 Seepage", Bureau of Indian Standards, pp 1-9

11.IS: 11315 (1987)"Method for quantitative description of discontinuities in rock masses, Part- 9, Number of Sets", Bureau of Indian Standards, pp 1-9

12.IS: 11315 (1987)"Method for quantitative description of discontinuities in rock masses, Part- 10, Block Size", Bureau of Indian Standards, pp 1-9

13.IS: 11315 (1987)"Method for quantitative description of discontinuities in rock masses, Part- 11, Core Recovery and Rock Quality Designation", Bureau of Indian Standards, pp 1-7

14.IS: 11315 (1987)"Method for quantitative description of discontinuities in rock masses, Part- 12, Drill Core Studies, ", Bureau of Indian Standards, pp 1-12

15.IS 11358(1987): Glossary of Terms and Symbols relating to Rock Mechanics

16.IS:13365-Part1 (1998) Quantitative classification system of rock mass- Guidelines , Part-1, Rock Mass Rating (RMR) for predicting Engineering properties, pp 1-11

17.IS:13365-Part3(1997) Quantitative classification system of rock mass- Guidelines , Part3, Determination of Slope Mass Rating(SMR), pp 1-6

18.Palmstrom, A. (1996)RMi - A System for Characterizing Rock Mass Strength for Use in Rock Engineering, Jr. Rock Mech. and Tunneling Technolog3', India, Vol. 1, No.2, pp.69-108

Thank you!!!