

Part II

User's Guide to the Atlas and Glossary

II-1

Classification Basis of the Photogeologic Geounits

The logic underlying the classification of the geounits is essentially the same as that which supports other forms of geologic mapping. Varnes (1974) has stated

“Four fundamental categories of attributes apply to (geologic) maps; these pertain to time, space, the inherent qualities or properties of real matter, and the relations of objects. Geologic units commonly are defined by combinations of these four kinds of attributes.”

The typological individuals of the classification conform to these attributes and their nomenclature conforms to accepted geoscience usage.

II-2

Selection Criteria of the Geounits

The following criteria were used in selecting the specific geohazard related geounits from the general classification.

- That the typological individuals be detectable and recognizable in current operational civil satellite images and airphotos with a spatial resolution range of sub-metric to 1 km, subject to other factors conditioning observability (Sect. II-3.2).
- That the classification includes all the major terrestrial environments.
- That the units possess a compositional homogeneity with respect to a number of observable and inferred attributes.
- That the units be significant in broader engineering and environmental terms.

The approach chosen to document the type units has been to examine airphoto coverage and satellite images of *known lithologies and structures* located in the various terrestrial environments. Reproductions of representative photos and images studied were thus progressively incorporated in the data sets of the geounit files as the group of illustrations in support of their textual characterizations.

II-3

Characterization of the Classification

II-3.1

Purpose

Geological and geomorphological interpretation and mapping requires the use of a set of descriptor codes to designate geounits. The codes best consist of combinations

of alpha-numeric symbols (Fulton 1993). The complete set of descriptors constitutes a terrain classification system. When the units are compiled as a photogeologic map these codes can also become the map legend.

II-3.2

Mappability of Photogeologic Geounits

The expression of a geounit within a photo or image, and hence its mappability, is conditioned by a number of factors:

- sufficient distinction in lithologic composition or structure occurring in a terrain
- nature of the denudational processes that act or have acted on it
- environment in which it presently occurs
- spectral characteristics of geologic materials in outcrop
- spectral characteristics of associated vegetation or land-use
- spatial, spectral and temporal resolutions of the sensor system that acquired the imagery or airphoto
- data processing techniques employed to generate the image
- available background information
- aptitude of the person performing the interpretation

Subject to the above factors, a given photogeologic interpretation or map will result in geologic information of differing specificity and accuracy.

II-3.3

Relationship to Other Image-Based Geo-Science Terrain Classifications

Beginning in the 1950s a number of systematic treatments of genetic terrain units were formulated for the interpretation of stereoscopic vertical air photographs in what has become recognized as the field of Photogeology. A notable example of this is the manual by Howes and Kenk (1988).

Since the advent of multispectral scanners aboard Earth-Observation satellites in the 1970s, a number of texts dealing with remote sensing in geology and geomorphology have appeared. A comprehensive lexicon of lithologic geology was not central to the purposes of these works. Only Meijerink (1988) and Short and Blair (1986) contain classifications approximating the systematization introduced here. The listings of Terrain Mapping Units in Meijerink (1988) is incidental to the presentation of a GIS-compatible methodology, while Short and Blair (1986) focus on structural (rather than lithologic) patterns associated with tectonic terranes and selected denudational land-form categories as they appear on the early Landsat images. Mesoscale units best resolved on airphotos are not considered in that book.

II-3.4

Present Professional Context of the Classification

In his advanced text on the use of remote sensing in the geological sciences Scanvic (1993) stated:

(the geoscience community) "... can anticipate methodological developments whose aims are to optimize the application of remote sensing techniques to the traditional activities of the (field) geologist. This applies particularly to the photo-image analyst who is attempting to gain an understanding of the geological environment of a given area. It proceeds from the normal synthesizing of multi bits of photo-image and extra-image evidence (integrated as distinct terrain units), currently the most operational photo-image interpretation method directed to the goal of an objective characterization of the terrain." (author's translation).

II-4

Organization of the Classification

The classification is ordered in 4 lithologic and structural Divisions and 19 Genetic Groups.

II-4.1

Division 1: Magmatic Rocks and Structures

The Units of this Division are primary igneous rock bodies lithified or welded.

Genetic Groups of this Division include:

- extrusive microlithic magmas
- pyro- and volcanoclastic deposits
- modern volcanic structures
- modern epiclastic deposits

II-4.2

Division 2: Sedimentary Rocks and Duricrusts

This Division consists of 5 Genetic Groups:

- carbonates
- saline and phosphatic rocks
- detrital rocks
- interbedded sequences
- duricrusts

Note: No metamorphic rocks appear in the present classification. As stated by Ehlen (1983) none of the three common classifications for predicting metamorphic rocks, textural, facies and formational, were found adequate for use on airphotos. Subsequent remote sensing

research indicates a potential possibility for identification of these rock types spectrally.

- Pre-Phanerozoic cratonic metamorphic rocks, like intrusive magmatic rocks, do not have geohazard relations as defined in this glossary.
- Non-cratonic metamorphic rocks that have geohazard relations are low-grade slate and schist. Due to their cleavages and foliations these rocks are susceptible to mechanical weathering and erosion in the same manner as siltstones and lutites among detrital and interbedded rocks.

II-4.3

Division 3: Geostructures

The Structural Units are areas of deformation and displacement of rocks of Divisions 2, 3 and 4. Three structural Groups include:

- gravity structures
- fault line traces
- general lineaments

II-4.4

Division 4: Surficial Deposits

With the exception of the basinal sediments and paraglacial groups, Geounits of this Division result from the transport and deposition in an unconsolidated state of materials eroded from the rocks and structures of the other Divisions by subaerial and marine denudation processes.

Genetic Groups of Surficial Deposits include:

- aeolian deposits
- basinal sediments
- fluvial system sediments
- marine littoral systems
- paraglacial geosystems
- periglacial-related forms
- mass movement materials

II-5

Geounit Terminology

The Classification contains four types of typological individuals: *Geostructures*, *Geounits*, *Variants* and *Components*. They are defined and symbolically designated as follows.

II-5.1

Geostructure

Definition. A Geostructure is a geounit of macro or meso scale which occurs in one of two modes:

- as a portion of or all of the mass of a rock Unit which has been subjected to particular diastrophic processes
- as a macroscopic scale Unit in its own right

Designation. A Geostructure is designated by conventional geological map symbols and by numeric codes as indicated for individual units in the Division.

II-5.2

Geounit

Definition. Photogeologically a geounit is a portion of a tract of land having *recognizable boundaries* at appropriate photo or imagery scales and whose overall homogeneity is a function of its genesis, composition, geologic structure and relief type.

A geounit approximates in conception the pedologist's "polypedon" (Gerrard 1981, pp 6–7) and the engineering geologist's "lithologic type" (IAEG 1981, pp 252–253).

Designation. A geounit is identified by a pairing of a single upper case letter code and number, when it is part of a Group (e.g. **X1** for a (undisturbed) basalt flow); or by an upper and lower case letter combination and number when it is part of a Sub-group (e.g. **Ed1** for linear dunes).

The alpha character codes for Genetic Groups are given in Table II.1.

Table II.1. Alpha character codes for the Geounits of Divisions 1, 2 and 4

Code	Group	Division
A	Modern volcanic epiclastic deposits	Magmatic
B	Marine littoral systems	Surficial
D	Duricrusts	Sedimentary
E	Aeolian deposits	Surficial
F	Fluvial system sediments	Surficial
G	Paraglacial geosystems	Surficial
H	Saline and phosphatic rocks	Sedimentary
K	Carbonates	Sedimentary
L	Basinal sediments	Surficial
M	Mass movement materials	Surficial
P	Tephra deposits	Magmatic
S	Detrital rocks	Sedimentary
V	Volcanic structures	Magmatic
W	Interbedded sequences	Sedimentary
X	Extrusive magmas	Magmatic
Z	Periglacial-related forms	Surficial

II-5.3 Variant

Definition. The Variant is a photo-image distinguishable 'facies' resulting from the action of one of a number of geologic or environmental factors. It is genetically assignable to a parent geounit. A variety of geologic factors are illustrated in the following examples. (Refer to the classification tables for the geological designations.)

- genesis, e.g. **Fv1.2**, **Zm1.2**
- diagenesis, e.g. **Ps1.1**, **S1.2**
- tectonism, e.g. **X1.3**
- relative age, e.g. **Ms1.1**
- morphology, e.g. **Mv1.1**, **Ed1.1**
- topographic site, e.g. **X1.2**
- climatic occurrence, e.g. **Bb1.1**

Designation. A Variant is identified by a number following the Unit designation, (e.g. Variant **S2.1** – lutite dissected facies of Unit **S2** – lutites undifferentiated).

Table II.2.
Geological timescale and
age symbols

EON	ERA		PERIOD		EPOCH			
PHANEROZOIC	Cn	CENOZOIC	Q	Quaternary	R	<i>Holocene</i>		
					Pl	<i>Pleistocene</i>		
			T	Tertiary	Po	<i>Pliocene</i>		
					Mc	<i>Miocene</i>		
					Og	<i>Oligocene</i>		
					E	<i>Eocene</i>		
					Pe	<i>Paleocene</i>		
					M	MESOZOIC	K	Cretaceous
	Kl	<i>Lower</i>						
	J	Jurassic						
	Tr	Triassic						
	Pz	PALEOZOIC	Pm Permian					
			Cb	Carboniferous			Cbu	<i>Upper</i>
							Cbl	<i>Lower</i>
			D	Devonian				
			S	Silurian				
			O	Ordovician				
			C	Cambrian				
			Pc	PRECAMBRIAN				
	Pr	PROTEROZOIC						
	Ar	ARCHEAN						
(HADEAN)								

II-5.4 Component

Definition. A Component is a mesoscale deposit or landform produced by genetic, structural or erosional processes. It has the following attributes:

- functionally integrated with the parent Unit
- dimensions are smaller than the parent Unit

Designation. Components are indicated by a qualifying lower case letter descriptor following the Unit or Variant designation (e.g. **Fv2b** – a levee within a low energy alluvial deposit Unit polygon; **L3c** clay-salt temporal wet zone).

II-5.5 Relative Chronology

Existing geological maps may enable interpreters to specify the age relations of adjacent geounits or superposed sequences of units. Suggested symbols of a general temporal nomenclature that may be used in such cases are listed in Table II.2.

II-6

Mode of Designation of Mapped Units

The degree of certainty of identification and designation of geounits that is achievable in any photo-image interpretation is conditioned by the factors listed in Sect. II-3.2:

Subject to those factors, an interpreter may combine descriptor codes of the classification to geounits that have been delineated and about which he/she can be more specific. For example, composition codes may be added to structural rock units or other deposits. Some specific examples are:

- **2-S1.1** designates not only a cuesta in layered rocks, but more specifically one in stabilised cemented sandstones
- **Br2.1-X1** designates an unstable high rock cliff of basalt
- **Mv2-S2/S1.2** designates a rock avalanche in shale beds overlying a mass of weakly-cemented sandstones
- relative thickness and superposition of certain surficial deposits (fluvial, lacustrine, glacial) when interpretable may be designated by use of a fractional code:
 - **Zi4/L2** designates ice wedge polygons developed on glaciolacustrine sediments
 - **Ef1/X1** designates sand sheets flowing over a basalt flow field

References

- Fulton RJ (1993) Surficial geology mapping at the Geological Survey of Canada: Its evolution to meet Canada's changing needs. Canadian Journal of Earth Sciences, vol 30, p 237
- Gerrard AJ (1981) Soils and landforms. George Allen and Unwin, London
- Matula M (1981) Rock and soil description and classification for engineering geological mapping. Report by the IAEG Commission on Engineering Geological Mapping. Bull. IAEG no 24, pp 235–274
- Mejerink AMJ (1988) Data acquisition and data capture through terrain mapping units. ITC Jour., 1988-1.
- Scanvic J-Y (1983) Utilisation de la télédétection dans les sciences de la terre, BRGM, France, Manuel et méthodes, no 7
- Short NM, Blair RW Jr (eds) (1986) Geomorphology from Space. NASA SP 486
- Varnes DJ (1974) The logic of geological maps, with reference to their interpretation and use for engineering purposes. USGS Professional Paper 837

General Bibliography

- Bell FG (1999) Geological hazards: Their assessment, avoidance and mitigation. Taylor & Francis
- Hayden RS (1985) Geomorphological similarity and uniqueness. NASA Conference Publ. 2312, Global Mega-Geomorphology, pp 21–22
- Howard JA, Mitchell CW (1985) Phytogeomorphology. John Wiley & Sons, New York
- Hunt RE (2007) Geologic hazards: A field guide for geotechnical engineers. Taylor & Francis
- IAEG Bull (1981) No 23, pp 235–274
- Kusky TM (2003) Geological hazards: A sourcebook. Greenwood Publishing Group

Soeters R, van Westen C (1996) Landslides: investigation and mitigation. Special Report 247. Transportation Research Board, National Research Council, Washington, D.C.

Thomas MF (1974) Tropical geomorphology. Macmillan, London, pp 158–159

Waltham T (2002) Foundations of engineering geology, 2nd edn. Spon Press, London, pp 74–75

Select Bibliography of Remote Sensing Technology for Geologic Interpretation

Optical Airphotogeology

- Allum JAE (1966) Photogeology and regional mapping. Pergamon Press, Oxford
- Ehlen J (1981) The identification of rock types in an arid region by air photo patterns. US Army Corps of Engineers Topographic Labs, ETL-0261
- Ehlen J (1983) The classification of metamorphic rocks and their applications to air photo interpretation procedures. US Army Corps of Engineers, Topographic Labs, ETL-0341
- Ehlers M, Hermann J, Kaufmann UM (2004) Remote sensing for environmental monitoring, GIS applications and geology. Society of Photographic Instrumentation Engineering
- Keser N (1976) Interpretation of landforms from aerial photographs. Province of British Columbia, Ministry of Forests
- Lueder DR (1959) Aerial photographic interpretation. McGraw-Hill, New York
- Mekel JFM (1970) The use of aerial photos in geology and engineering. ITC Textbook of Photo Interpretation, vol VIII. International Institute for Aerial Survey and Earth Sciences
- Miller VC (1961) Photogeology. McGraw-Hill, New York
- Mollard JD, Janes JR (1983) Airphoto interpretation and the Canadian landscape. Surveys and Mapping Branch, Department of Energy Mines and Resources, Canada
- Ray RG (1960) Aerial photographs in geologic interpretation and mapping. USGS Professional Paper 373
- Summerson CH (1954) A philosophy for photo interpreters. Photogrammetric Engineering 20(3):396
- Townshend JRG (ed) (1981) Terrain analysis and remote sensing. George Allen & Unwin, London
- Tricart JS, Rimbart S, Lutz G (1970) Introduction à l'utilisation des Photographies Aériennes en Géographie, Géologie Écologie. SEDES, France
- Verstappen HTh (1977) Remote sensing in geomorphology. Elsevier Scientific Publishing Co., NY
- van Zuidam RA (1985/86) Aerial photo interpretation in terrain analysis and geomorphological mapping. Smits Publishers/ITC, The Hague
- von Bandat HF (1962) Aerogeology. Gulf Publishing Company, Houston, Texas

Electro-Optical Satellite Imageries

- Amaral G (1984) Remote sensing systems comparisons for geological mapping in Brazil. Proceedings, IUGS/UNESCO Seminar, Remote Sensing for Geological Mapping, pp 91–106
- Berger Z (1994) Satellite hydrocarbon exploration. Springer-Verlag, Berlin
- Blodget HW, Brown GF (1982) Geological mapping by use of computer enhanced imagery in Western Saudi Arabia. USGS Professional Paper 1153
- de Silva S, Francis PW (1991) Volcanoes of the Central Andes. Springer-Verlag, Berlin

- Drury SA (1987) Image interpretation in geology. Allen & Unwin, London
- Gupta RP (1991) Remote sensing geology. Springer-Verlag, Heidelberg
- Prost GL (2002) Remote sensing for geologists: A guide to image interpretation. Gordon & Breach
- Williams RS, Marsh SE (1983) Geological applications. Manual of remote sensing 2nd edn, Chap. 31. American Society of Photogrammetry
- Radar Geology**
- Dallemand JF, Lichtenegger J, Raney RK, Schumann R (1993) Radar imagery: Theory and interpretation. Remote Sensing Centre, Food and Agriculture Organization, United Nations, RSC Series No 67
- RADARSAT International (1996) RADARSAT geology handbook, Client Services
- Sabins FF (1999) Geologic mapping and remote sensing. Proceedings, Thirteenth International Conference on Applied Geologic Remote Sensing, Vancouver. pp I-41, I-42
- Scanvic JY (1993) Télédétection aérospatiale et informations géologiques. BRGM, France, Manuel et méthodes, no. 24
- Siegal BS, Gillespie AR (1980) Remote sensing in geology. John Wiley & Sons, New York
- Singhroy VH (ed) (1994) Special issue on radar geology. Canadian Journal of Remote Sensing 20(3): 197–349
- Singhroy VH, Kenny FM, Barnett PJ (1989) Radar imagery for Quaternary geological mapping in glaciated terrains. Proceedings, 7th Thematic Conference on Remote Sensing for Exploration Geology, pp 591–600
- Trautwein CM, Taranik JV (1978) Analytic and interpretive procedures for remote sensing data. USGS, Sioux Falls, S.D.
- van Sleen LA (1984) Analysis of MSS Landsat data for small-scale soil surveys in the humid tropics. Proceedings, 18th ERIM Remote Sensing Symposium, pp 1973–1982

<http://www.springer.com/978-3-540-20296-7>

Geohazard-associated Geounits

Atlas and Glossary

Rivard, L.A.

2009, XX, 1056 p. With CD-ROM., Hardcover

ISBN: 978-3-540-20296-7