Encyclopedia of Planetary Landforms
DOI 10.1007/978-1-4614-9213-9_55-1

Colluvial Deposit

Susan W. S. Millar*
Department of Geography, Syracuse University, Syracuse, NY, USA

Synonyms

Colluvial depositional system; Colluvial mantle; Colluvial soil; Colluvium; Debris slope; Hillslope (or hillside) deposits; Scree (UK); Slope mantle; Slope-waste deposits; Talus (US)

Definition

A sedimentary deposit composed of surface mantle that has accumulated toward the base of a slope as a result of transport by gravity and non-channelized flow.

Description

The International Geomorphological Association recognizes colluvium as a hillslope deposit resulting from two general nonexclusive processes (Goudie 2004). Rainwash, sheetwash, or creep can generate sediment accumulations at the base of gentle slopes; or non-channelized flow can initiate sheet erosion and toe-slope sediment accumulation. The term “colluvium” is frequently applied broadly to include mass wasting deposits in a variety of topographic and climatic settings. For example, Blikra and Nemec (1998) describe colluvium as any “clastic slope-waste material, typically coarse grained and immature, deposited in the lower part and foot zone of a mountain slope or other topographic escarpment, and brought there chiefly by sediment-gravity processes.” Lang and Honscheidt (1999) describe colluvium as “slope wash and tillage sediments, resulting from soil erosion. . ..” The composition of a colluvial deposit can therefore be coarse-grained, eroded bedrock, with an open-work structure and several meters thick (Blikra and Nemec 1998), to fine-grained soil, ranging from a few millimeters to meters in thickness (e.g., Lang and Hönscheidt 1999). Some deposits may exhibit distinct macro- and micro-fabric development, bedding structures, and evidence of distinct periods of accumulation (e.g., Bertran et al. 1997; Pederson et al. 2000; Millar and Nelson 2001). Morphological expression can include gentle, curvilinear slope profiles, steep rectilinear slopes, or incipient gullying and lobe forms, dependent on rate of movement, sediment type, water content, post-depositional modification, and time since deposition (see Coe et al. 2008 and articles therein). The scope of formative mechanisms results in the presence of colluvial deposits in all climatic environments from tropical (Hiruma et al. 2012) to high latitude (Blikra and Nemec 1998).

---

*Email: swmillar@maxwell.syr.edu

Fig. 1 Talus cone formed at the base of a bedrock gully, Lofoten, Norway (Photo by Susan W. S. Millar)

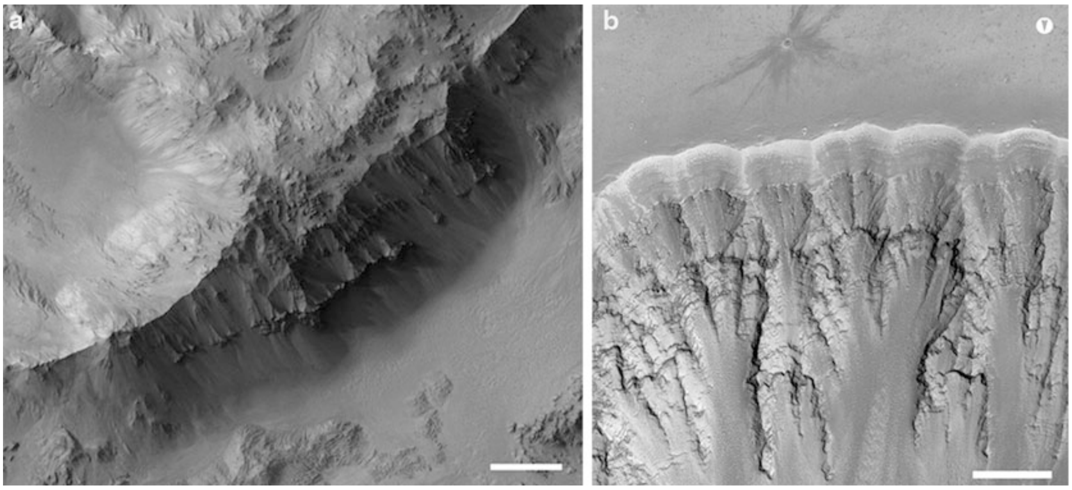

Fig. 2 (**a**) Talus cones on Mars, Mojave Crater (Williams and Malin 2008). CTX P01_001481_1874_XI_07N033-W. Scale bar 1 km. (NASA/JPL/MSSS). (**b**) The walls of one of the depressions of the eastern Noctis Labyrinthus. Colluvium probably consists primarily of rocky debris. The dark rayed crater is on the upland plain above the depression. MOC2-1411 near: 10°S, 265°E. Scale bar ca. 500 m. South is up (NASA/JPL/Malin Space Science Systems)

Subtypes

Colluvial deposits have no diagnostic morphometric characteristics, but can illustrate certain features and forms indicative of the dominant type of mass wasting processes responsible for their movement. (See descriptions under ► Mass Wasting Processes, ► Rock Glacier, ► Protalus Features, ► Mass wasting, ► Denivation.) Several compound terms are used to describe colluvial slope deposits, primarily based on the dimension and extent of the deposit. Slope angle is dependent on a number of factors including sorting, grain-size, and the presence of interstitial ice (e.g., Graham 1984).

(1) A talus cone is a cone-shaped landform at the base of a cliff or escarpment that is sourced in a relatively small declivity or ravine (NSSH 2008; Figs. 1 and 2). The ravine is also called rock fall funnel (Rapp 1960), which is “a half-funnel-shaped excavation in a rock wall, wide above,

DOI 10.1007/978-1-4614-9213-9_55-1

Fig. 3 Talus fan produced by rock-slide, Banff, Canada (Photo by Susan W. S. Millar)

Fig. 4 Talus slope, Maroon Bells, Colorado, USA (Photo by Susan W. S. Millar)

narrow below, through which debris moves by rock-falls." The narrow mouth of the funnel is called gorge (Rapp 1960).

(2) Talus fans (colluvial fan) are common on mountain slopes (slope fan), often accumulating at the base (Fig. 3). Typically they are composed of immature gravel; the coarsest debris is situated in the lower (toe) zone. They are produced by rock fall, debris flow, or snow flow, with minor contributions from waterflows from gullies. Their gradient is 35–45° near the apex, 15–20° near the toe. On Earth they are typically <0.5 km large (Blikra and Nemec 1998) (cf. ▶ Alluvial Fan).

(3) A talus slope (debris slope, scree slope) is a hillslope mantled by talus (NSSH 2008; Figs. 4 and 5) consisting of an accumulation of "[r]ock fragments of any size or shape (usually coarse and angular) derived from and lying at the base of a cliff or very steep, rocky slope" (Bates and Jackson 1980, p. 638). If it is stratified, it is called a bedded colluvium. Minor albedo variations of added rockfall material can cause slight streaking of talus slopes on Earth. On Mars, significant albedo variations are seen in talus ▶ Slope Streaks (Williams 1991).

(4) A debris apron (talus apron, colluvial apron) is a thick wedge-shaped deposit of colluvium and/or slope alluvium (NSSH 2008). It is composed of coalesced talus fans that may surround a hill, ▶ Plateau, Mesa, Butte; or comprise a (▶ Blockfield, ▶ Protalus Features, ▶ Rock Glacier). Debris apron is a term predominantly applied today in the planetary geomorphology

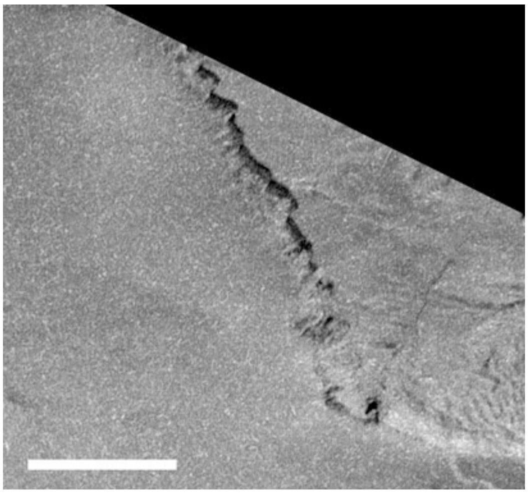

Fig. 5 Cliff-forming debris (talus) slopes at the southwestern margin of Tvashtar plateau on Io (Moore et al. 2004, Fig. 3). Galileo 05273457.01 at 61°N, 120°W (NASA/JPL)

Fig. 6 Mesa on Mars with debris apron in West Candor Chasma. Scale bar 500 m. (MOC r2100326) (NASA/JPL/MSSS)

literature (Fig. 6); similar terrestrial features are usually termed talus or colluvial fans, although "apron" has been used to describe colluvial slope morphology (e.g., Coe et al. 2008). Stewart and Crown (1997) have described subtypes of debris aprons in the eastern Hellas region of Mars, as lobate or arcuate, morphologies dependent upon their landform associations.

DOI 10.1007/978-1-4614-9213-9_55-1

Interpretation

Macro-fabrics (Mills 1991; Millar 2005) and micro-fabrics (Bertran et al. 1997) have some utility in differentiating specific types of mass movement processes responsible for the emplacement of colluvial deposits, as well as identifying the influence of freezing and thawing on sediments (Millar and Nelson 2001). Grain-size characteristics and the degree of soil development are useful indicators of depositional processes, time since deposition and the stability of the surface (e.g., Schaetzl and Anderson 2005). The presence of surface features such as gullies, levees, and lobes may indicate the mechanism of downslope movement or the post-depositional modification of a previous colluvial surface. Micromorphological features observed in soils, such as silt caps and deformed sediment, can indicate the operation of ice, and freezing and thawing (e.g., Bockheim and Tarnocai 1998).

Formation

Regolith or in situ weathered bedrock can be mobilized by a variety of gravity transfer processes commonly referred to as ► mass wasting processes, and can include ► flows, ► slides, and ► creep. Associated with gravity transfer due to stress-strain relations and pore-water pressures in the colluvial mass implicit in flow, slide and creep, are a variety of possible triggers for transport initiation. These can include seismic activity (Keefer 1984), land-use change and agricultural activities (e.g., Lang and Hönscheidt 1999; Leopold and Völkel 2007), climatic change (Blikra and Nemec 1998; Pederson et al. 2000; Geertsema et al. 2006), and avalanching (e.g., Blikra and Nemec 1998; Decaulne and Saemundsson 2006).

Age

Terrestrial colluvial deposits can range from present-day to Cenozoic and older, often interbedded and with pedogenic development.

Degradation

Buried colluvial horizons retain little significant morphological expression, but may have remnant fabric signatures (e.g., Mills 1991; Pederson et al. 2000; Millar and Nelson 2001) and/or textural composition (e.g., Blikra and Nemec 1998; Nemec and Kazanci 1999) that can help identify specific emplacement mechanisms.

Surface/Structural Units

In some cases discrete morphological features may be present that are indicative of specific and/or localized mass-wasting processes. These may include rockfall boulders, protalus ramparts, slump blocks, ► Periglacial Landforms, ► rock glaciers, etc.

DOI 10.1007/978-1-4614-9213-9_55-1

Fig. 7 Simulated astronauts' work on a colluvial deposit. Mars Desert Research Station, Utah, USA (Photo by H. Hargitai)

Composition

Colluvial deposits are typically heterogeneous, open-work sedimentary masses, but can vary in grain-size characteristics from fine silts and clays to large, freshly weathered bedrock (Fig. 7). The degree of sorting can range from high, as in surface wash deposits, to very poor sorting, as in rock glaciers or debris flows.

Distribution and Studied Locations

Colluvial deposits occur on any hillslope, thus are evident in all climatic environments. Terrestrial examples are ubiquitous. Some examples include:

(1) Unglaciated Eastern United States (Cremeens et al. 2003; Millar and Nelson 2001; Todd and Kite 2010; Fig. 8)
(2) Western Norway (Blikra and Nemec 1998; Blikra and Selvik 1998)
(3) Central Europe (Lang and Hönscheidt 1999; Lang 2003; Leopold and Völkel 2007)

Significance

Colluvial deposits are important stores of sediments. The presence of debris aprons and debris flow deposits on Mars are suggestive of ice-rich surficial material that has thawed and flowed during periods of warmer climatic conditions (Lanza et al. 2010).

Fig. 8 Open-work, blocky slope mantle of periglacial colluvium (▶ Blockfield), W. Virginia, USA (Photo by Susan W. S. Millar)

Astrobiological Significance

The presence of flowing material suggests that liquid water may have existed thus providing a foundation for life-forms to evolve.

Planetary Analogs

Colluvial deposits on Mars have mean inclinations as low as 20° that suggests formation by gravitational creep driven by repeated deposition and sublimation of ground ice. Impact-triggered mass wasting processes or thermal expansion may have only minor contribution to debris slope sediment transport (Perron et al. 2003).

Distribution

On Mars, extensive colluvial deposits occur at the base of bedrock escarpments in impact craters, outflow channels, chasmae (canyons), fossae (graben), etc., over much of the Martian surface but are most abundant at intermediate southern latitudes (Perron et al. 2003). The eastern Hellas region has prominent debris aprons with superimposed lobate forms and gullies that Stewart and Crown (1997) interpret as degradational forms associated with slope instability on upland massifs and on inner crater rims. Malin and Edgett (2000) describe areas of seepage on the Martian surface that exhibit a source area, transportation slopes and channels, and a debris apron at the toe (▶ Gully). HiRISE images enabled a morphometric analysis to establish area-source relations and morphologies commonly found in terrestrial analogs of shallow surface debris flows.

Age

Martian colluvial deposits are associated with the Amazonian starting approximately 1.8 billion years ago and a general cooling of the planet.

History of Investigation

Although not specified as colluvial, the effects of creep on the slope waste mantle were investigated and debated by Geikie (1877) and Thomson (1877) in the late nineteenth century. Geomorphologists such as W.M. Davis (1899) and G.K. Gilbert (1909) understood the importance of wash and creep and graded waste slopes in their discussions of hillslope evolution. Emerson (1941) used the term "colluvial soils" to describe loam soils that accumulate at the base of a slope, leaving a stonier lag deposit mid-slope, as a result of creep and surface runoff. Early application of the term to relict periglacial deposits by Denny (1951) replaced the more commonly used waste deposits or "warp" of Bryan (1946). By the 1970s colluvium was entrenched in the literature to encapsulate both fine- and coarse-grained slope materials that have undergone some downslope movement. This is in contrast to ► regolith, which assumes that the waste material is in situ weathered bedrock. Non-terrestrial slope deposits are rarely designated as "colluvial," the preference being to define them more specifically on the basis of the possible mechanisms that were responsible for their transport and deposition.

Origin of Term

The term derives from Latin "colluvies," meaning "offscourings" (OED 2012). It is used to distinguish between slope, non-channelized deposits, and alluvium. Original usage was presented by Johnson (1880): "Colluvial soils . . . while consisting in part of drift or alluvium, also contain sharp angular fragments of the rock from which they mainly originated."

See Also

► Blockfield
► Gully
► Lobate Debris Apron
► Sand Ramp
► Slope
► Slope Streak

References

Bates RL, Jackson JA (eds) (1980) Glossary of geology. American Geological Institute, Falls Church

Bertran P, Hétu B, Texier J-P, van Steijn H (1997) Fabric characteristics of subaerial slope deposits. Sedimentology 44:1–16

Blikra LH, Nemec W (1998) Postglacial colluvium in Western Norway: depositional processes, facies and palaeoclimatic record. Sedimentology 45:909–959

Blikra LH, Selvik S (1998) Climatic signals recorded in snow avalanche-dominated colluvium, Western Norway: depositional facies successions, chronostratigraphy and pollen records. The Holocene 8:631–658

Bockheim JG, Tarnocai C (1998) Recognition of cryoturbation for classifying permafrost-affected soils. Geoderma 81:281–293

Bryan K (1946) Cryopedology – the study of frozen ground and intensive frost-action with suggestions on nomenclature. Am J Sci 244:622–642

Coe JA, Kinner DA, Godt JW (2008) Initiation conditions for debris flows generated by runoff at Chalk Cliffs, Central Colorado. Geomorphology 96:270–297

Cremeens DL, MacDonald DH, Lothrop JC (2003) Holocene colluvial soils and geoarchaeology in the unglaciated appalachian plateau: two examples from West Virginia, USA. Geoarchaeology 18:799–826

Davis WM (1899) The geographical cycle. Geogr J 14:481–504

Decaulne A, Saemundsson T (2006) Geomorphic evidence for present-day snow-avalanche and debris-flow impact in the Icelandic Westfjords. Geomorphology 80:80–93

Denny CS (1951) Pleistocene frost action near the border of the Wisconsin drift in Pennsylvania. Ohio J Sci 51:116–125

Emerson FV (1941) A colluvial soil and its people. Am Geogr Soc 46:655–658

Emerson FV (1914) Bulletin of the American Geographical Society, 46(9):655–658

Geertsema M, Clague JJ, Schwab JW, Evans SG (2006) An overview of recent large catastrophic landslides in Northern British Columbia, Canada. Eng Geol 83:120–143

Geikie J (1877) The movement of the soil cap. Nature 15:397–398

Gilbert GK (1909) The convexity of hilltops. J Geol 17:344–350

Goudie A (2004) Colluvium. In: Encyclopedia of geomorphology. International Association of Geomorphologists: Routledge, New York

Graham J (1984) Methods of stability analysis. In: Brundsden D, Poor DB (eds) Slope instability. Wiley, Chichester

Hiruma ST, Modenesi-Gauttieri MC, Riccomini C (2012) Late quaternary colluvial deposits in the Bocaina Plateau, Southeastern Brazil highlands: age and palaeoenvironmental consequences. Boreas 42:306–316

Johnson SW (1880) How crops feed: a treatise on the atmosphere and the soil as related to the nutrition of agricultural plants. Orange Judd, New York

Keefer DK (1984) Landslides caused by earthquakes. Geol Soc Am Bull 95:406–421

Lang A (2003) Phases of soil erosion-derived colluviation in the loess hills of South Germany. Catena 51:209–221

Lang A, Hönscheidt S (1999) Age and source of colluvial sediments at Vaihingen-Enz, Germany. Catena 38:89–107

Lanza NL, Meyer GA, Okubo CH, Newsom HE, Wiens RC (2010) Evidence for debris flow gully formation initiated by shallow subsurface water on Mars. Icarus 205:103–112

Leopold M, Völkel J (2007) Colluvium: definition, differentiation, and possible suitability for reconstructing Holocene climate data. Quat Int 162–163:133–140

Malin MC, Edgett KS (2000) Evidence for recent groundwater seepage and surface runoff on Mars. Science 288:2330–2335

Millar SWS (2005) Fabric variability associated with periglacial mass-wasting at Eagle Summit, Alaska. Geomorphology 72:222–237

Millar SWS, Nelson FE (2001) Clast fabric in relict periglacial colluvium, Salamanca re-entrant, Southwestern New York, USA. Geogr Ann A Phys Geogr 83:145–156

Mills HH (1991) Three-dimensional clast orientation in glacial and mass-movement sediments: a compilation and preliminary analysis. U S Geol Surv Open File Rep 90–128:71

Moore JM, Sullivan RJ, Chuang FC, Head JW III, McEwen AS, Milazzo MP, Nixon BE, Pappalardo RT, Schenk PM, Turtle EP (2001) Landform degradation and slope processes on Io: the Galileo view. J Geophys Res E: Planets 106:33223–33240

Moore et al. (2004) Journal of Geophysical Research E: Planets 106(E12):33223–33240

Nemec W, Kazanci N (1999) Quaternary colluvium in West-Central Anatolia: sedimentary facies and palaeoclimatic significance. Sedimentology 46:139–170

NSSH (2008) Glossary of landform and geologic terms. National soil survey handbook, part 629, 430-VI-NSSH

OED (2012) Oxford English dictionary. Oxford University Press, Oxford. http://www.oed.com/

Pederson J, Pazzaglia F, Smith G (2000) Ancient hillslope deposits: missing links in the study of climate controls on sedimentation. Geology 28:27–30

Perron JT, Dietrich WE, Howard AD, McKean JA, Pettinga JR (2003) Ice-driven creep on martian debris slopes. Geophys Res Lett 30(14):1747. doi:10.1029/2003GL017603

Rapp A (1960) Talus slopes and mountain walls at Tempelfjorden, Spitsbergen: a Geomorphological Study of the Denudation of Slopes in an Arctic Locality. Norsk Polarinstitutt Skrifter 119, Oslo University Press, Oslo

Schaetzl RJ, Anderson S (2005) Soils: genesis and geomorphology. Cambridge University Press, Cambridge

Stewart KS Crown DA (1997) Geomorphology of debris aprons in the Eastern Hellas region of Mars. Lunar Planet Sci XXVIII

Thomson CW (1877) The movement of a soil-cap. Nature 15:359–360

Todd G, Kite JS (2010) Geomorphology and pedology of a mixed alluvial-colluvial deposit in Central West Virginia: new insight into appalachian landscape evolution. Southeast Geol 47:27–39

Williams SH (1991) Dark talus steaks on Mars are similar to aeolian dark streaks. Lunar Planet Sci XXII:1509–1510

Williams RME, Malin MC (2008) Sub-kilometer fans in Mojave crater, Mars. Icarus 198:365–383