William M. White
Encyclopedia of Geochemistry
Encyclopedia of Earth Sciences Series
10.1007/978-3-319-39193-9_97-1

# Epigenesis

Jamie J. Wilkinson[1, 2]
(1)Department of Earth Sciences, Natural History Museum, London, UK
(2)Department of Earth Science and Engineering, Imperial College, London, UK

**Jamie J. Wilkinson**
**Email:** j.wilkinson@nhm.ac.uk

## Without Abstract

## Definition

Epigenesis is a term derived from the Greek (epi+genesis = after formation) that is primarily used to describe a geological process involving the addition, modification, and/or removal of minerals from a rock subsequent to its formation. It typically refers to a *metasomatic* process that has, as well as transforming the mineral assemblage, modified the chemical composition and even textural properties of the bulk rock via the addition or removal of elements. The term may be applied in geomorphology to the formation of glacial valleys, in soil science to soil formation, and in sedimentology to the process of formation of a mineral, texture, or structure subsequent to compaction – thus partly synonymous with *diagenesis* . However, it is most commonly used in geochemistry in relation to the formation of mineral deposits – in particular those formed from *hydrothermal solutions* such as sediment-hosted mineral deposits (Brown, *2014*; Ramanaidou and Wells, *2014*; Wilkinson, *2014*) and volcanogenic massive sulfide deposits (Franklin et al., *1981*).

## Epigenetic mineral deposits

The early subdivision of mineral deposits into those that formed by *syngenesis* (process of formation similar to that which formed the enclosing rock and, in modern usage, also implying a temporal connection) and *epigenesis* (introduced into a preexisting rock) recognized the fundamental difference in mineral deposit morphology that can result from these end-member processes (Lindgren, *1913*). The morphology is important for mineral exploration and mining because different methods are used to recognize and mine ore from *syngenetic* deposits that are lenticular and conformable with stratigraphic units (described as *stratiform*) and *epigenetic* deposits that may have tabular, pipelike, or irregular geometries that are contained within specific stratigraphic units ( *stratabound)* or crosscut stratigraphy. In sedimentary ore systems, there is overlap in the usage of terms, with *syngenesis* often considered synonymous with *early diagenesis* and *epigenesis* with *late diagenesis* (or *epidiagenesis* ; particularly in the USA). *Syndiagenesis* has been used as a term by economic geologists to separate the stages of syngenesis and epigenesis (e.g., Bartholomé et al., *1972*; Boast et al., *1981*). In carbonate sedimentology, *syndiagenesis* is broadly synonymous with *eogenesis* .

Epigenetic deposits may form in two general ways: either by infiltration of fluids into intergranular porosity with precipitation of ore and gangue minerals in pore space and by replacement of existing grains or by infiltration of fluids along fracture permeability or brecciated zones with precipitation of minerals to form veins or breccia cements. Gradations between the two end-members frequently occur, where mineralization spreads into the wall rocks surrounding vein systems or into breccia clasts. Replacement can be either highly selective, preserving primary rock components such as fossils or primary rock-forming minerals and textures, or may be texturally destructive so that primary features are obscured.

# Controversy regarding the syngenetic or epigenetic origin of mineral deposits

The distinction between syngenesis and epigenesis is not straightforward and has led to extensive debate in the literature surrounding the processes responsible for the formation of certain types of mineral deposits, such as sediment-hosted Pb-Zn deposits (e.g., Leach et al., *2005*). *Syngenesis*, as applied to sediment-hosted or volcanogenic massive sulfide deposits, implies that ore-forming processes occurred near the water-sediment interface, effectively in connection with the hydrosphere and biosphere. By contrast, *epigenesis* can have occurred tens or hundreds of millions of years after rock lithification, potentially at significant burial depths, and possibly at high temperatures. Clearly, the processes involved in the transport and precipitation of ore-forming elements in such contrasting regimes are very different. The relative timing of ore formation also has major implications for mineral exploration: syngenetic deposits are likely to be found in a specific stratigraphic interval in a particular terrane, whereas epigenetic deposits could be found in any suitably receptive rocks that are older than the hydrothermal system involved. In a number of cases, both genetic models have been proposed for the same ore deposits, with perhaps the best-known examples being the Proterozoic sediment-hosted Zn-Pb deposits of the McArthur Basin in Australia (Large et al., *1998*; Perkins and Bell, *1998*) and the Carboniferous deposits of the Irish Midlands orefield (Hitzman and Beaty, *1996*; Wilkinson et al., *2005*). The principal arguments for the timing of mineralization are based on geological relationships and textural observations – whether the ore minerals form stratigraphically conformable sedimentary layers that can be accounted for by deposition from suspension in water or if they can be shown to transgress stratigraphic contacts and replace preexisting minerals in the rock. Unfortunately, where a mineral deposit is subject to post-formation diagenetic, tectonic, or metamorphic overprinting, remobilization of minerals can obscure primary depositional textures and generate secondary "epigenetic" characteristics. Thus, because of the ambiguity often present in such observations, research efforts increasingly utilize isotope geochemistry or geochronology to distinguish between syngenesis and epigenesis (e.g., Hnatyshin et al., *2015*).

# Mineral systems with syngenetic and epigenetic components

Other complications include the fact that syngenetic deposits can also have epigenetic components in the form of vein, breccia, and/or alteration "feeder" zones that underlie the main deposit, such as in sedimentary-exhalative (SEDEX) deposits (Leach et al., *2005*) or volcanic-hosted massive sulfide deposits (Franklin et al., *1981*). These reflect the upward passage of buoyant hydrothermal fluids into the ore-forming environment and so are an intrinsic part of the overall hydrothermal system. The temporal relationship between the metasomatic process and rock lithification implicit in the term *epigenesis* is also subject to ambiguity when the host rocks are carbonate rich. Such rocks lithify very quickly, potentially at the seafloor (Bathurst, *1970*); as a result, strictly epigenetic processes and textures can be generated, although the processes are effectively operating within the syngenetic domain (e.g., Wilkinson and Hitzman, *2014*).

## Summary

*Epigenesis* has wide usage in the geoscience literature but is most commonly applied in the description of mineral deposits. Because it describes a genetic process that may not be easily constrained from the rock record, and because it also represents an "end-member" of a spectrum of linked processes, its usage is quite commonly controversial. For more details on distinctions between the usage of "epigenesis," "diagenesis," and "syngenesis" in the context of mineral deposits, see Misra ( *2000*).

## Cross-references

- Diagenesis
- Hydrothermal solution
- Metasomatism
- Ore deposits
- Syngenesis

## References

Bartholomé, P., Evrard, P., Katekesha, F., Lopez-Ruiz, J., and Ngongo, M., 1972. Diagenetic ore-forming processes at Kamoto, Katanga, Republic of the Congo. In Amstutz, G. C., and Bernard, A. J. (eds.), *Ore in Sediments*. New York: Springer-Verlag, pp. 21–41.

Brown, A. C., 2014. Low-temperature sediment-hosted copper deposits. In Holland, H. D., and Turekian, K.K. (eds.), *Treatise on Geochemistry*, 2nd edn. Geochemistry of Mineral Deposits, Elsevier: Amsterdam, Vol. 13, pp. 251–272.

Franklin, J. M., Sangster, D. M., and Lydon, J. W., 1981. Volcanic-associated massive sulfide deposits. In Skinner, B. J., (ed.), *Economic Geology 75th Anniversary Volume*, Pennsylvania: Lancaster Press, pp. 485–626.

Hitzman, M. W., and Beaty, D. W., 1996. The Irish Zn-Pb-(Ba) orefield. In Sangster, D. F., (ed.), *Carbonate-Hosted Lead-Zinc Deposits*. Littleton, CO: Society of Economic Geologists, Special publication, Vol. 4, pp. 112−143.

Misra, K., 2000. *Understanding Mineral Deposits* Netherlands: Springer, Ch. 4, pp. 228−237.

Ramanaidou, E. R., and Wells, M. A., 2014. Sedimentary hosted iron ores. In Holland, H. D., and Turekian, K. K., (eds.), *Treatise on Geochemistry*, 2nd edn. Geochemistry of Mineral Deposits, Amsterdam: Elsevier, Vol. 13. pp. 313−356.

Wilkinson, J. J., 2014. Sediment-hosted zinc-lead mineralization: processes and perspectives. In Holland, H. D. and Turekian, K. K., (eds.), *Treatise on Geochemistry*, 2nd edn. Geochemistry of Mineral Deposits, Amsterdam: Elsevier, Vol. 13, pp. 219−250.

Wilkinson, J. J., and Hitzman, M. W., 2014. The Irish Zn-Pb Orefield: the view from 2014. In: Archibald, S. M., and Piercey, S. J., (eds.), *Current Perspectives in Zinc Deposits*. Dublin: Irish Association of Economic Geology, pp. 59−73.

Bathurst, R. G. C., 1970. Problems of lithification in carbonate muds. *Proceedings of the Geologists' Association*, **81**, 429−440.

Boast, A. M., Coleman, M. L., and Halls, C., 1981. Textural and stable isotopic evidence for the genesis of the Tynagh base metal deposit, Ireland. *Economic Geology*, **76**, 27−55.

Hnatyshin, D., Creaser, R. A., Wilkinson, J. J., and Gleeson, S. A., 2015. Re-Os dating of pyrite confirms an early diagenetic onset and extended duration of mineralization in the Irish Zn-Pb orefield. *Geology*, **43**, 143−146.

Large, R. R., Bull, S. W., Cooke, D. R., and McGoldrick, P. J., 1998. A genetic model for the HYC deposit, Australia: based on regional sedimentology, geochemistry, and sulphide−sediment relationships. *Economic Geology*, **93**, 1345−1368.

Leach, D. L., Sangster, D. F., Kelley, K. D., Large, R. R., Garven, G., Allen, C. R., Gutzmer, J., and Walters, S., 2005. Sediment-hosted lead-zinc deposits: a global perspective. *Economic Geology* (100th Anniversary Volume, **1905−2005**), 561−607.

Lindgren, W., 1913. *Mineral Deposits*, 1st edn., New York: McGraw-Hill Book Company, Vol. 11, pp. 140–165.

Perkins, W. G., and Bell, T. H., 1998. Stratiform replacement lead-zinc deposits: a comparison between Mount Isa, Hilton, and McArthur River. *Economic Geology*, **93**, 1190–1212.

Wilkinson, J. J., Everett, C. E., Boyce, A. J., Gleeson, S. A., and Rye, D. M., 2005. Intracratonic crustal seawater circulation and the genesis of sub-seafloor Zn-Pb mineralization in the Irish orefield. *Geology*, **33**, 805–808.