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Editorial

Editorial for Special Issue "Structural Control of Mineral Deposits: Theory and Reality"

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"Structural Control" remains a crucial point that is frequently absent in scientific and/or economic analyses of ore deposits, whatever their type and class, although a selection of references illustrates its importance [1–5]. The case of lode deposits is particularly adapted, but other types, like breccia pipes, stockwork, massive sulphides, skarn, etc., also concern Structural Control. Works on the Structural Control of ore deposits are not abundant in the recent literature, and, as frequently suggested, structural geology often is not sufficiently developed in the exploration programs of many mining camp's strategies. A few compilations have been devoted to this theme in the last two decades, such as (i) the special publication of the Geological Society of London, concerned with the link between fracturing, flow, and mineralization [6], (ii) the review of the Society of Economic Geology, devoted to Structural Control [7], (iii) a special publication of the Geological Society of London, looking to study the genetic link that can exist between mineralization and orogenic domains [8], and finally, (iv) a special issue of the Journal of Structural Geology, devoted to the application of Structural Geology in mineral exploration and mining [9]. In addition to these four compilations, only a few publications have been concerned with this theme, and most of them are dated before the year 2000. These publications mostly concerned vein internal infilling textures [10,11], the vein formation model, with the contribution and controversy of the crack seal, dissolution-precipitation, diffusion, and seismic-valves mechanisms (e.g., [12–16]). In his review, Chauvet [17] discussed of some of these concepts, in order to highlight the role and the significance of pre-existing structures in the formation of vein-style deposits.

Three publications of this volume explore the development of mineralization in the specific context of orogenic domains. Cugerone et al. [18] offer a detailed study of a rather complex Pb–Zn mineralisation developed within the orogenic Hercynian Pyrenees during two mineralization stages, each of them linked with a deformational event. The syntectonic primary mineralization is remobilized and helps the formation of the second one. The same approach is used within the two following contributions on the same theme [19,20]. Funedda et al. [19] and Fridovsky et al. [20] also used a detailed description of the relationships between mineralization and deformation in deformed domains, such as the Variscan domain of Sardinia and the Verkhovansk-Kolyma folded region of NE Russia. Funedda et al. [19] pay close attention to the opening process of structures that will serve as traps for mineralised fluid catching, a fact that is fundamental in any tectonic understanding of a mineralised vein system [17]. Fridovsky et al. [20] also proposed a pluri-deformational model associated with multiple stages of mineralisation formation.

The relationship between magmatism, regional tectonic context, and mineralization remain a question that has still been debated in several recent publications [21,22], thus demonstrating that this question is still relevant and may help in the distinction between intrusion-related, orogenic deposits and the Cu–Au-rich porphyry types. Two contributions explore new methods of investigation that provide an innovative vision of the relationship between magmatism and mineralization. Song et al. [23] examine the consequences of the telescoping of two mineralized systems (a subsequent epithermal system affects a primary porphyric one within the Tiegelongnan Porphyry and the epithermal overprinting Cu (Au) deposit, Central Tibet, China) with a focus on the role of the dislocation effects on ore reserve calculations and future deposits discoveries. Tuduri et al. [24] suggest an original way to demonstrate the genetic link between mineralization and magmatism by establishing that both are developed in the same regional tectonic context, in the highly mineralised Moroccan Anti-Atlas. This contribution represents an indirect but efficient way to relatively date the emplacement of magmatism and mineralization formations, and their relationships.

In the past, the concept of a gold-bearing shear zone has not given satisfying results in terms of our understanding of gold deposits, and has been more or less totally abandoned, except within few specific sectors of the Canadian shield in which the role of major crustal faults is still at the centre of the accepted models [25]. In the domain of economic geology, faults are fundamental structures that can have two contrasting behaviours: (i) Hydrogeological barriers that help the concentration of ore, as demonstrated by the contribution of Grare et al. [26] in the case of the Kiggavik uranium example (Canada), and (ii) a zone of permeability that can favour fluid circulation and can serve as a guide for the mineralisation trapping. The work of Maciel et al. [27] proposes a surprising example in which fault occurrences have a negative role for clay authigenesis efficiency; this work also discusses the consequence on reservoir characteristics. Sun et al. [28] end the section on relations with brittle tectonics by presenting an innovative GIS-based spatial analysis of mineral deposit patterns in correlation with detailed structural features, in order to propose some implications on Structural Control. The chosen example was provided from the Copper deposit of the Tongling Ore district of Eastern China.

Concerning other orebodies than vein-type ones, volcanic-hosted massive sulphide deposits (VHMS) have been recently the subject of much debate, specifically with the suggestion of a significant contribution of "replacement processes" in their modes of formation [29,30]. In addition, it has been demonstrated that stockwork within VHMS environments can result in subsequent syntectonic veining instead of earlier veins related to feeder zones [31]. Indeed, the observation of stockwork within a VHMS context needs to be considered with particular attention because of the possible coexistence of the two types of stockwork: the one related to the feeder zone and the other the result of subsequent deformation [17]. It has been suggested that the second event and associated metal may contribute significantly to a relative enrichment in VHMS environment. Without any reference to some replacement process, the contribution of Admou et al. [32] ends the special issue with a very attractive formation model of the Moroccan Guemassa VHMS deposit, strongly involving the active role of normal faults and Structural Control, since the beginning of the volcanic activity. In fact, it appears that most of the VHMS deposits certainly do not present the classical geometrical model exhibited within all teaching books, but instead form by wall-rock replacement (metasomatism) strongly helped by the re-using of pre-existing structures, such as folds, unconformities, and/or fault and deformation features. Such a contribution is frequently underestimated.

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References

1. Forde, A.; Bell, T.H. Late structural control of mesothermal vein-hosted gold deposits in Central Victoria, Australia: Mineralization and exploration potential. *Ore Geol. Rev.* **1994**, *9*, 33–59. [CrossRef]
2. Davis, B.K.; Hippertt, J.F.M. Relationships between gold concentration and structure in quartz veins from the Hodgkinson Province, northeastern Australia. *Mineral. Depos.* **1998**, *33*, 391–405. [CrossRef]
3. Chauvet, A.; Piantone, P.; Barbanson, L.; Nehlig, P.; Pedroletti, I. Gold deposit formation during collapse tectonics: Structural, mineralogical, geochronological, and fluid inclusion constraints in the Ouro Preto gold mines, Quadrilátero Ferrífero, Brazil. *Econ. Geol.* **2001**, *96*, 25–48. [CrossRef]
4. Chauvet, A.; Bailly, L.; André, A.S.; Monié, P.; Cassard, D.; Llosa Tajada, F.; Vargas, J.R.; Tuduri, J. Internal vein texture and vein evolution of the epithermal Shila-Paula district, southern Peru. *Mineral. Dep.* **2006**, *41*, 387–410. [CrossRef]

5. Tunks, A.J.; Cooke, D.R. Geological and structural controls on gold mineralization in the Tanami District, Northern Territory. *Mineral. Dep.* **2007**, *42*, 107–126. [CrossRef]
6. McCaffrey, K.; Lonergan, L.; Wilkinson, J. *Fractures, Fluid Flow and Mineralization*; Geological Society of London Special Publication: London, UK, 1999; Volume 155, 328p.
7. Richards, J.P.; Tosdal, R.M. Structural Controls on Ore Genesis. In *Reviews in Economic Geology*; Society of Economic Geologists, Inc.: Littleton, CO, USA, 2001; 181p.
8. Blundell, D.J.; Neubauer, F.; Von Quadt, A. *The Timing and Location of Major Ore Deposits in an Evolving Orogen*; Geological Society of London Special Publication: London, UK, 2002; Volume 204, 358p.
9. Vearncombe, J.R.; Blenkinsop, T.G.; Reddy, S.M. Applied Structural Geology for Mineral Exploration and Mining. *J. Struct. Geol.* **2004**, *26*, 989–994. [CrossRef]
10. Dowling, K.; Morrison, G. Application of quartz textures to the classification of gold deposits using North Queensland examples. *Econ. Geol. Mon.* **1990**, *6*, 342–355.
11. Dong, G.; Morrison, G.; Jaireth, S. Quartz textures in epithermal veins, Queensland - classification, origin, and implication. *Econ. Geol.* **1995**, *90*, 1841–1856. [CrossRef]
12. Ramsay, J.G. The crack-seal mechanism of rock deformation. *Nature* **1980**, *284*, 135–139. [CrossRef]
13. Cox, S.F.; Etheridge, M.A. Crack-seal fibre growth mechanism and their significance in the development of oriented layer silicate microstructures. *J. Struct. Geol.* **1983**, *92*, 147–170. [CrossRef]
14. Bons, P.D.; Jessell, M.W. Experimental simulation of the formation of fibrous veins by localised dissolution-precipitation creep. *Mineral. Mag.* **1997**, *61*, 53–63. [CrossRef]
15. Boullier, A.M.; Robert, F. Paleoseismic events recorded in Archean gold quartz vein networks, Val-Dor, Abitibi, Quebec, Canada. *J. Struct. Geol.* **1992**, *14*, 161–177. [CrossRef]
16. Bons, P.D.; Elburg, M.A.; Gomez-Rivas, E. A review of the formation of tectonic veins and their microstructures. *J. Struct. Geol.* **2012**, *43*, 33–62. [CrossRef]
17. Chauvet, A. Structural Control of Ore Deposits: The Role of Pre-existing Structures on the Formation of Mineralised Vein Systems. *Minerals* **2019**, *9*, 56. [CrossRef]
18. Cugerone, A.; Oliot, E.; Chauvet, A.; Gavaldà Bordes, J.; Laurent, A.; Le Goff, E.; Cenki-Tok, B. Structural Control on the Formation of Pb-Zn Deposits: An Example from the Pyrenean Axial Zone. *Minerals* **2018**, *8*, 489. [CrossRef]
19. Funedda, A.; Naitza, S.; Buttau, C.; Cocco, F.; Dini, A. Structural Controls of Ore Mineralization in a Polydeformed Basement: Field Examples from the Variscan Baccu Locci Shear Zone (SE Sardinia, Italy). *Minerals* **2018**, *8*, 456. [CrossRef]
20. Fridovsky, V.Y.; Kudrin, M.V.; Polufuntikova, L.I. Multi-Stage Deformation of the Khangalas Ore Cluster (Verkhoyansk-Kolyma Folded Region, Northeast Russia): Ore-Controlling Reverse Thrust Faults and Post-Mineral Strike-Slip Faults. *Minerals* **2018**, *8*, 270. [CrossRef]
21. Dressel, B.C.; Chauvet, A.; Trzaskos, B.; Biondi, J.C.; Bruguier, O.; Monié, P.; Villanova, S.N.; Newton, J.B. The Passa Tres lode gold deposit (Parana State, Brazil): An example of structurally-controlled mineralisation formed during magmatic-hydrothermal transition and hosted within granite. *Ore Geol. Rev.* **2018**, *102*, 701–727. [CrossRef]
22. Tuduri, J.; Chauvet, A.; Barbanson, L.; Labriki, M.; Dubois, M.; Trapy, P.H.; Lahfid, A.; Poujol, M.; Melleton, J.; Badra, L.; et al. Structural control, magmatic-hydrothermal evolution and formation of hornfels-hosted, intrusion-related gold deposits: Insight from the Thaghassa deposit in Eastern Anti-Atlas, Morocco. *Ore Geol. Rev.* **2018**, *97*, 171–198. [CrossRef]
23. Song, Y.; Yang, C.; Wei, S.; Yang, H.; Fang, X.; Lu, H. Tectonic Control, Reconstruction and Preservation of the Tiegelongnan Porphyry and Epithermal Overprinting Cu (Au) Deposit, Central Tibet, China. *Minerals* **2018**, *8*, 398. [CrossRef]
24. Tuduri, J.; Chauvet, A.; Barbanson, L.; Bourdier, J.L.; Labriki, M.; Ennaciri, A.; Badra, L.; Dubois, M.; Ennaciri-Leloix, C.; Sizaret, S.; Maacha, L. The Jbel Saghro Au(–Ag, Cu) and Ag–Hg Metallogenetic Province: Product of a Long-Lived Ediacaran Tectono-Magmatic Evolution in the Moroccan Anti-Atlas. *Minerals* **2018**, *8*, 592. [CrossRef]
25. Poulsen, K.H.; Robert, F. Shear zones and gold: Practical examples from the southern Canadian Shield. *Geol. Assoc. Can. Short Course Notes* **1989**, *6*, 239–266.

26. Grare, A.; Lacombe, O.; Mercadier, J.; Benedicto, A.; Guilcher, M.; Trave, A.; Ledru, P.; Robbins, J. Fault Zone Evolution and Development of a Structural and Hydrological Barrier: The Quartz Breccia in the Kiggavik Area (Nunavut, Canada) and Its Control on Uranium Mineralization. *Minerals* **2018**, *8*, 319. [CrossRef]
27. Maciel, I.B.; Dettori, A.; Balsamo, F.; Bezerra, F.H.R.; Vieira, M.M.; Nogueira, F.C.C.; Salvioli-Mariani, E.; Sousa, J.A.B. Structural Control on Clay Mineral Authigenesis in Faulted Arkosic Sandstone of the Rio do Peixe Basin, Brazil. *Minerals* **2018**, *8*, 408. [CrossRef]
28. Sun, T.; Xu, Y.; Yu, X.; Liu, W.; Li, R.; Hu, Z.; Wang, Y. Structural Controls on Copper Mineralization in the Tongling Ore District, Eastern China: Evidence from Spatial Analysis. *Minerals* **2018**, *8*, 254. [CrossRef]
29. Aerden, D.G.A.M. Formation of Massive Sulfide Lenses by Replacement of folds: The Hercules Pb–Zn Mine, Tasmania. *Econ. Geol.* **1993**, *88*, 377–396. [CrossRef]
30. Perkins, W.G. Mount Isa lead-zinc orebodies: Replacement lodes in a zoned syndeformational copper–lead–zinc system? *Ore Geol. Rev.* **1997**, *12*, 61–110. [CrossRef]
31. Chauvet, A.; Onézime, J.; Charvet, J.; Barbanson, L.; Faure, M. Syn- to late-tectonic stockwork emplacement within the Spanish section of the Iberian Pyrite Belt: Structural, textural and mineralogical constraints in the Tharsis-La Zarza areas. *Econ. Geol.* **2004**, *99*, 1781–1792. [CrossRef]
32. Admou, S.; Branquet, Y.; Badra, L.; Barbanson, L.; Outhounjite, M.; Khalifa, A.; Zouhair, M.; Maacha, L. The Hajjar Regional Transpressive Shear Zone (Guemassa Massif, Morocco): Consequences on the Deformation of the Base-Metal Massive Sulfide Ore. *Minerals* **2018**, *8*, 435. [CrossRef]