

Towards the development of a genetic classification of mud volcanism: An analytical review

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Abstract

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Abstract. Genetic characteristic of mud volcanism is essential for assessing and predicting mud volcanic hazard, as well as for studying the geo- and fluid dynamics of sedimentary sections. With the regular discovery of new areas of mud volcanism, more and more data is emerging on its heterogeneity and various genetic characteristics. This paper attempts to identify and systematically organize its genetic types, based on an analysis of numerous publications. Following genetic types of mud volcanism were identified: classical, giant submarine landslide, gas hydrate, serpentinite, deglacial, abyssal, and intraplate rift structures. Their characteristics and distinctive features are presented. The classical type of mud volcanism is the most widespread and studied. It exhibits the greatest diversity in the morphology and size of mud volcanic edifices, as well as structural and tectonic controls and geodynamic position. Three evolutionary stages of mud volcanism – initial, main, and final – were distinguished, with three evolutionary types identified, respectively. The initial stage features small fluid-generation foci and corresponds to the stage of sedimentary basin subsidence, with biogenic methane generation. It may be preceded and accompanied by the intense discharge of fluids (methane and/or water), leading to the formation of pockmarks. The main stage is the longest and corresponds to the subsidence of fluid-generating strata into a catagenesis zone, with thermogenic methane generation and smectite illitization. The final evolutionary stage of classical mud volcanism marks the demise of the mud volcanic system as a result of its uplift and denudation, as well as the exhaustion of thermogenic methane generation. Classical mud volcanism can be further classified by the contribution of deep fluid flows, including those from the mantle, as well as the presence of gas hydrates, and the participation of geothermal fluids. Within the gas hydrate genetic type, varieties can be distinguished based on the mechanism of fluid phase generation. The serpentinite type is the most distinctive in its characteristics. It occurs in suprasubduction zones as a result of the breakthrough of fluids generated during dehydration, decarbonization, and metamorphic reactions from a subducting plate under high pressure and low temperature. Deglacial, abyssal, and intraplate rift structures are the least studied types of mud volcanism and require further study and verification. The intraplate rift structure type might be classified as a geothermal system in sedimentary strata based on further research. Along with the identified genetic types of mud volcanism, its polygenic manifestations are also possible. The proposed genetic classification may be subject to criticism, but it is a necessary step that will spur research into this area.

Keywords:

mud volcanism, mud volcanoes, genetic classification, sedimentary basin, gas emission, gas hydrates

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References

1. Mazzini A., Etiope G. Mud volcanism: an updated review. *Earth-Science Reviews*. 2017,168:81–112. <https://doi.org/10.1016/j.earscirev.2017.03.001>
2. Somoza L., Medialdea T., Leon R., Ercilla G., Vazquez J.T., Farran M.I., Hernandez-Molina J., Gonzalez J., Juan C., Fernandez-Puga M.C. Structure of mud volcano systems and pockmarks in the region of the Ceuta Contourite Depositional System (Western Alborán Sea). *Marine Geology*. 2012,332-334:4–26. <http://dx.doi.org/10.1016/j.margeo.2012.06.002>
3. Judd A., Hovland M. *Seabed fluid flow: the impact on geology, biology and the marine environment*. Cambridge University Press, 2009, 492 p. <https://doi.org/10.1017/CBO9780511535918>

4. Yusubov N.P., Guliyev I.S. [Mud volcanism and hydrocarbon systems of the South Caspian Basin (based on the latest data from geophysical and geochemical studies)]. Baku: Elm, 2022, 168 p. (In Russ.).
5. Brown K.M. The nature and hydrogeologic significance of mud diapirs and diatremes for accretionary systems. *Journal of Geophysical Research*. 1990,95:8969–8982. <https://doi.org/10.1029/jb095ib06p08969>
6. Kopf A.J. Significance of mud volcanism. *Reviews of Geophysics*. 2002,40(2),52 p. doi:10.1029/2000RG000093
7. Loseth H., Wensaas L., Arntsen B., Hanken N.-M., Basire C., Graue K. 1000 m long gas blow-out pipes. *Marine and Petroleum Geology*. 2011,28:1047–1060. <https://doi.org/10.1016/j.marpetgeo.2010.10.001>
8. Bogoyavlensky V.I. New data on mud volcanism in the Arctic on the Yamal peninsula. *Doklady Earth Sciences*. 2023,512:847–853. <https://doi.org/10.1134/s1028334x23601116>
9. Leon R., Somoza L., Medialdea T., Maestro A., Diaz-del-Rio V., Fernandez-Puga M.C. Classification of sea-floor features associated with methane seeps along the Gulf of Cadiz continental margin. *Deep-Sea Research*. 2006,53(11-13):1464–1481. <https://doi.org/10.1016/j.dsr2.2006.04.009>
10. Pryce E., Kirkham C., Cartwright J. Crater formation during the onset of mud volcanism. *Geology*. 2023,51(3):252–256. <https://doi.org/10.1130/G50713.1>
11. Antipin V.S., Fedorov A.M., Pokrovsky B.G. Formation of the Patom crater by phreatic explosion: geological and isotope-geochemical evidence. *Lithology and Mineral Resources*. 2015,50(6):478–487. <https://doi.org/10.1134/S0024490215060024>
12. Isayev V.P., Isayev P.V., Rasvoszhaeva E.A. [Patomsky gaslithoclastite volcano]. *Oil and Gas Geology*. 2012,3:77–83. (In Russ.). <https://www.elibrary.ru/ozeovb>
13. Judd A. Gas emissions from mud volcanoes. Significance to global climate change. In: Martinelli G., Panahi B. (eds) *Mud volcanoes, geodynamics and seismicity: NATO Science Series, Series IV: Earth and Environmental Series*. Dordrecht: Springer, 2005, 51, p. 147–157. <https://doi.org/10.1007/1-4020-3204-8>
14. Milkov A.V. Worldwide distribution of submarine mud volcanoes and associated gas hydrates. *Marine Geology*. 2000,167(1-2):29–42. [https://doi.org/10.1016/S0025-3227\(00\)00022-0](https://doi.org/10.1016/S0025-3227(00)00022-0)
15. Gubkin I.M., Fedorov S.F. [Mud volcanoes of the Soviet Union and their connection with the genesis of oil fields of the Crimean-Caucasian geological province]. Moscow: Publ. of the USSR Academy of Sciences, 1938, 44 p. (In Russ.).
16. Glumov I.F., Gulev V.L., Karnaukhov S.M., Senin B.V. [Regional geology and oil and gas potential of the Black Sea deep-sea basin and adjacent shelf zones]. Pt. 2. Moscow: Nedra, 2014, 181 p. (In Russ.).
17. Guliev I.S., Yusubov N.P., Guseynova S.M. On the formation mechanism of mud volcanoes in the South Caspian basin according to 2D and 3D seismic data. *Izvestiya, Physics of the Solid Earth*, 2020,56(5):721–727. <https://doi.org/10.1134/S106935132005002X>
18. Glazyrin E.A. [Main results of the study of underwater mud volcanism of the Kerch-Taman region]. In: *Modern problems of geology, geophysics and geoecology of the North Caucasus*. Moscow: IIET RAN, 2017, vol. 7, pt. 2: 39–48. (In Russ.).
19. Glazyrin E.A. [On forecasting mud volcano eruptions and assessing the hazard of mud volcanic activity on the Kerch-Taman shelf]. In: [Patterns of formation and impact of marine and atmospheric hazardous phenomena and disasters on the coastal zone of the Russian Federation in the context of global climatic and industrial challenges ("Hazardous Phenomena"): Proceedings of the International Scientific Conf., Rostov-on-Don, June 13–23, 2019]. Rostov-on-Don: Publ. of the Southern Scientific Center of RAS, 2019, p. 37–39 (In Russ.).
20. Glazyrin E.A. [State monitoring of the subsoil condition of the coastal-shelf zone of the Azov, Black and Caspian seas – main results and development prospects]. In: *Modern problems of geology, geophysics and geoecology of the North Caucasus*. Moscow: IIET RAN, 2020, vol. 10, pt. 2: 325–332. (In Russ.).
21. Glazyrin E.A., Karpenko A.N., Karpenko G.E., Leshchenko D.P., Marfin A.A., Prokoptsev G.N., Silchenko A.Y. [Information bulletin on the state of the subsoil of the coastal-shelf zones of the Azov, Black and Caspian seas in 2023]. Moscow: Nauchnaya biblioteka [Scientific library], 2024, 122 p. (In Russ.).
22. Glazyrin E.A., Glazyrina N.V. [Ust-Chekupskoe mud volcanic field of the Kerch-Taman mud volcanic region]. In: *Modern problems of geology, geophysics and geoecology of the North Caucasus*. Moscow: IIET RAS, 2025, vol. 15: 260–265. (In Russ.).
23. Tinivella U., Giustiniani M. An overview of mud volcanoes associated to gas hydrate system. In: Nemeth K. (ed.) *Updates in volcanology – New advances in understanding volcanic systems*. 2012, p. 225–267. <http://dx.doi.org/10.5772/51270>
24. Milkov A.V. Global distribution of mud volcanoes and their significance in petroleum exploration as a source of methane in the atmosphere and hydrosphere and as a geohazard. In: Martinelli G., Panahi B. (eds) *Mud volcanoes, geodynamics and seismicity: NATO Science Series, Series IV: Earth and Environmental Series*. Dordrecht: Springer, 2005, 51, p. 29–34. https://doi.org/10.1007/1-4020-3204-8_3
25. Ismagilov A.F., Kozlov V.N., Terekhov A.A., Khortov A.V. [Clay diapirism and mud volcanism in the formation of local structures in the Russian part of the Black Sea]. *Geology, Geophysics and Development of Oil and Gas Fields*. 2006,2:4–10. (In Russ.). <https://www.elibrary.ru/hsnkk1>
26. Kholodov V.N. [Mud volcanoes: distribution and genesis]. *Geology and Mineral Resources of the World Ocean*. 2012,4(30):5–27. (In Russ.). <https://www.elibrary.ru/pjwoil>
27. Dimitrov L.I. Mud volcanoes – the most important pathway for degassing deeply buried sediments. *Earth-Science Reviews*. 2002,59:49–76. [https://doi.org/10.1016/S0012-8252\(02\)00069-7](https://doi.org/10.1016/S0012-8252(02)00069-7)
28. Kalinko M.K. [Mud volcanoes, causes of their occurrence, development and attenuation]. *Trudy VNIGNI [Proceedings of the All-Russian Research Geological Oil Institute]*. 1964,40:30–54. (In Russ.).
29. Kikvadze O.E., Lavrushin V.Yu., Pokrovskii B.G., Polyak B.G. Isotope and chemical composition of gases from mud volcanoes in the Taman Peninsula and problem of their genesis. *Lithology and Mineral Resources*. 2014,49:491–504. <https://doi.org/10.1134/S0024490214060066>
30. Kurishko V.A., Mesyats I.A., Terdovidov A.S. [Hydrogeology of mud volcanism of the Kerch Peninsula]. *Geological Journal*. 1968,28(1):49–59. (In Russ.).
31. Lavrushin V.Yu., Aydarkozhina A.S., Chelnokov G.A., Petrov O.L., Sokol E.V. Mud volcanic fluids of the Kerch-Taman region: geochemical reconstructions and regional trends. Communication 1: Geochemical features and genesis of mud-volcanic waters. *Lithology and Mineral Resources*. 2021,56:461–486. <https://doi.org/10.1134/S0024490221060043>
32. Lavrushin V.Yu., Kikvadze O.E., Pokrovsky B.G., Polyak B.G., Guliev I.S., Aliev A.A. Waters from mud volcanoes of Azerbaijan: isotopic-geochemical properties and generation environments. *Lithology and Mineral Resources*. 2015,50:1–25. <https://doi.org/10.1134/S0024490215010034>

33. Lavrushin V.Yu., Kikvadze O.E., Pokrovsky B.G., Aliev Ad.A., Polyak B.G. [Waters of mud volcanoes of the Caucasus region: geochemical features and formation conditions]. *Transactions of the Institute of Geology of the Dagestan Scientific Center of the Russian Academy of Sciences*. 2011,57:217–221. (In Russ.). <https://www.elibrary.ru/pxndyv>
34. Shnyukov E.F., Sobolevsky Y.V., Gnatenko G.K., Naumenko P.I., Kutniy V.A. [Mud volcanoes of the Kerch-Taman region]: Atlas. Kyiv: Naukova Dumka, 1986, 152 p. (In Russ.).
35. Milkov A.V., Sassen R., Apanasovich T.V., Dadashev F.G. Global gas flux from mud volcanoes: a significant source of fossil methane in the atmosphere and the ocean. *Geophysical Research Letters*. 2003,30(2):1037. <https://doi.org/10.1029/2002GL016358>
36. Mazzini A., Svensen H., Planke S., Guliyev I., Akhmanov G.G., Fallik T., Bank D. When mud volcanoes sleep: Insight from seep geochemistry at the Dashgil mud volcano, Azerbaijan. *Marine and Petroleum Geology*. 2009,26:1704–1715. <https://doi.org/10.1016/j.marpetgeo.2008.11.003>
37. Shnyukov E.F., Kobolev V.P. Blind mud volcanoes of the Black Sea. *Geology and Mineral Resources of the World Ocean*. 2020,16(2):49–65. (In Russ.). <https://doi.org/10.15407/gpimo2020.02.049>
38. Nazarov N.O. [Mud volcanoes of the Keymir-Chikishlyar region of southwestern Turkmenistan]. Ashgabat: Academy of Sciences of the Turkmen SSR, 1957, 117 p.
39. Aliyev Ad.A., Guliyev I.S., Dadashov F.H., Rahmanov R.R. *Atlas of world mud volcanoes*. Baku: Nafta-Press, 2015, 321 p.
40. Limonov A.F. Mud volcanoes. *Soros Educational Journal*. 2004,8(1):63–69. (In Russ.).
41. Kholodov V.N. Mud volcanoes, their distribution regularities and genesis. Communication 1. Mud volcanic provinces and morphology of mud volcanoes. *Lithology and Mineral Resources*. 2002,37:197–209. <https://doi.org/10.1023/A:1015425612749>
42. Mascle J., Mary F., Praeg D., Brosolo L., Camera L., Ceramicola S., Dupré S. Distribution and geological control of mud volcanoes and other fluid/free gas seepage features in the Mediterranean Sea and nearby Gulf of Cadiz. *Geo-Marine Letters*. 2014,34(2–3):89–110. <https://doi.org/10.1007/s00367-014-0356-4>
43. Bonini M. Mud volcanoes: Indicators of stress orientation and tectonic controls. *Earth-Science Reviews*. 2012,115:121–152. <http://dx.doi.org/10.1016/j.earscirev.2012.09.002>
44. Feyzullayev A.A. Mud volcanoes in the South Caspian basin: Nature and estimated depth of its products. *Natural Science*. 2012,4(7):445–453. <http://dx.doi.org/10.4236/ns.2012.47060>
45. Huseynov D.A., Guliyev I.S. Mud volcanic natural phenomena in the South Caspian Basin: geology, fluid dynamics and environmental impact. *Environmental Geology*. 2004,46:1012–1023. <https://doi.org/10.1007/s00254-004-1088-y>
46. Kopf A., Deyhle A., Lavrushin V.Y., Polyak B.G., Gieskes J.M., Buachidze G.I., Wallmann K., Eisenhauer A. Isotopic evidence (He, B, C) for deep fluid and mud mobilization from mud volcanoes in the Caucasus continental collision zone. *International Journal of Earth Sciences*. 2003,92:407–425. <https://doi.org/10.1007/s00531-003-0326-y>
47. Vanneste H., Kelly-Gerrey B.A., Connelly D.P., James R.H., Haeckel M., Fisher R.E., Heeschen K., Mills R.A. Spatial variation in fluid flow and geochemical fluxes across the sediment–seawater interface at the Carlos Ribeiro mud volcano (Gulf of Cadiz). *Geochimica et Cosmochimica Acta*. 2011,75:1124–1144. <https://doi.org/10.1016/j.gca.2010.11.017>
48. Ershov V.V., Sobisevich A.L., Puzich I.N. [Deep structure of Taman mud volcanoes based on field studies and mathematical modeling]. *Geophysical Research*. 2015,16(2):69–76. (In Russ.). <https://www.elibrary.ru/tvtubj>
49. Sobisevitch A.L., Gorbatiyov A.V., Ovsuchenko A.N. Deep structure of the Mt. Karabetov mud volcano. *Doklady Earth Sciences*. 2008,422:1181–1185. <https://doi.org/10.1134/S1028334X08070428>
50. Sobisevich A.L., Sobisevich L.E., Tveritinova T.Y. On mud volcanism in the late Alpine folded edifice of the Northwestern Caucasus (based on an example of the study of the deep structure of the Shugo mud volcano). *Geology and Mineral Resources of the World Ocean*. 2014,2(36):80–93. (In Russ.).
51. Shnyukov E.F., Aliev Ad.A., Rakhmanov R.R. Mud volcanism of the Mediterranean, Black and Caspian seas: specifics of development and manifestations. *Geology and Mineral Resources of the World Ocean*. 2017,2(48):5–25. (In Russ.). <https://www.elibrary.ru/zjstkd>
52. Shnyukov E.F., Netrebskaya E.Y. [On the deep structure of the eruptive vent of mud volcanoes]. *Geology and Mineral Resources of the World Ocean*. 2016,4(46):54–66. (In Russ.). <https://www.elibrary.ru/xsbzar>
53. Stadnitskaia A., Blinova V., Ivanov M.K., Baas M., Hopmans E., van Weering T.C.E., Sinninghe Damste J.S. Lipid biomarkers in sediments of mud volcanoes from the Sorokin Trough, NE Black Sea: Probable source strata for the erupted material. *Organic Geochemistry*. 2007,38(1):67–83. <https://doi.org/10.1016/j.orggeochem.2006.08.012>
54. Hensen C., Nuzzo M., Hornibrook E., Pinheiro L.M., Bock B., Magalhaes V.H., Bruckmann W. Sources of mud volcano fluids in the Gulf of Cadiz – indications for hydrothermal imprint. *Geochimica et Cosmochimica Acta*. 2007,71(5):1232–1248. <https://doi.org/10.1016/j.gca.2006.11.022>
55. Lavrushin V.Yu., Kopf A., Deyhle A., Stepanets M.I. Formation of mud-volcanic fluids in Timan (Russia) and Kakheta (Georgia): evidence from boron isotopes. *Lithology and Mineral Resources*. 2003,38:120–153. <https://doi.org/10.1023/a:1023452025440>
56. Etiope G., Baciuc C.L., Schoell M. Extreme methane deuterium, nitrogen and helium enrichment in natural gas from the Homorod seep (Romania). *Chemical Geology*. 2011,280(1–2):89–96. <https://doi.org/10.1016/j.chemgeo.2010.10.019>
57. Etiope G., Feyzullayev A., Baciuc C.L. Terrestrial methane seeps and mud volcanoes: A global perspective of gas origin. *Marine and Petroleum Geology*. 2009,26(3):333–344. <https://doi.org/10.1016/j.marpetgeo.2008.03.001>
58. Baciuc C., Caracausi A., Etiope G., Italiano F. Mud volcanoes and methane seeps in Romania: main features and gas flux. *Annals of Geophysics*. 2007,50(4):501–511. <https://doi.org/10.4401/ag-4435>
59. Leon R., Somoza L., Medialdea T., Hernandez-Molina F.J., Vazquez J.T., Diaz-del-Rio V., Gonzalez F.J. Pockmarks, collapses and blind valleys in the Gulf of Cádiz. *Geo-Marine Letters*. 2010,30(3–4):231–247. <https://doi.org/10.1007/s00367-009-0169-z>
60. Cartwright J., Kirkham C., Espinoza D.N., James D., Hodgson N. The evolution of depletion zones beneath mud volcanoes. *Marine and Petroleum Geology*. 2023,155(7):106351. <https://doi.org/10.1016/j.marpetgeo.2023.106351>
61. Glazyrin E.A., Glazyrina N.V. [Neogene-Quaternary carbonate structures and formations of underwater gas-fluid discharges of the Azov-Taman region]. In: *Geology of reefs: Proceedings of All-Russian lithological meeting, June 15–17, 2015*, Syktyvkar. Syktyvkar: IG Komi SC UB RAS, 2015, p. 32–33. (In Russ.). <https://www.elibrary.ru/xrasdx>
62. Hovland M., Curzi P. Gas seepage and assumed mud diapirism in the Italian Central Adriatic Sea. *Marine and Petroleum Geology*. 1989,6(2):161–169. [https://doi.org/10.1016/0264-8172\(89\)90019-6](https://doi.org/10.1016/0264-8172(89)90019-6)
63. Paull C.K., Dallimore S.R., Caress D.W., Gwiazda R., Melling H., Riedel M., Jin Y.K., Hong J.K., Kim Y.-G., et al. Active mud volcanoes on the continental slope of the Canadian Beaufort Sea. *Geochemistry, Geophysics, Geosystems*.

64. Jiangxin C., Haibin S., Yongxian G., Shengxiong Y., Luis M.P., Yang B., Boran L., Minghui G. Morphologies, classification and genesis of pockmarks, mud volcanoes and associated fluid escape features in the northern Zhongjiannan basin, South China Sea. *Deep Sea Research. Part II: Topical Studies in Oceanography*. 2015,122:106–117. <https://doi.org/10.1016/j.dsr2.2015.11.007>
65. Shnyukov E.F., Ivanchenko V.V., Permyakov V.V. [Accessory mineralization of mud breccia of the Black Sea mud volcanoes. *Geology and Mineral Resources of the World Ocean*]. 2014,1(35):45–68. (In Russ.). <https://www.elibrary.ru/sjtlthp>
66. Shnyukov E.F., Netrebskaya E.Y. [Deep geological structure of mud volcanoes of the Black Sea]. *Geology and Mineral Resources of the World Ocean*. 2014,2(36):66–79. (In Russ.). <https://www.elibrary.ru/sjtltx>
67. Ginsburg G.D., Kremlev A.N., Grigoriev M.N., Larkin G.V., Pavlenkin A.D., Saltykova N.A. [Filtrogenic gas hydrates in the Black Sea (21st voyage of the R/V Evpatoria)]. *Geology and Geophysics*. 1990,31(3):10–20. (In Russ.).
68. Milkov A.V., Vogt P.R., Crane K., Lein A.Y., Sassen R., Cherkashev G.A. Geological, geochemical, and microbial processes at the hydrate-bearing Håkon Mosby mud volcano: a review. *Chemical Geology*. 2004,205(3-4):347–366. <https://doi.org/10.1016/j.chemgeo.2003.12.030>
69. Shnyukov E.F., Kobolev V.P. [Mud volcanic deposits of methane gas hydrates in the Black Sea]. *Geology and Mineral Resources of the World Ocean*. 2018,1(51):5–34. (In Russ.). <https://www.elibrary.ru/xoogep>
70. Shnyukov Y., Kobolev V., Yanko V. Mud-volcanic deposits of methane gas hydrates in the Black Sea. In: *Gas Hydrate Technologies: Global Trends, Challenges and Horizons – 2020*: E3S Web of Conferences. 2021,230(7):01005. <https://doi.org/10.1051/e3sconf/202123001005>
71. Loher M., Pape T., Marcon Y., Römer M., Wintersteller P., Praeg D., Torres M., Sahling H., Bohrmann G. Mud extrusion and ring-fault gas seepage – upward branching fluid discharge at a deep-sea mud volcano. *Scientific Reports*. 2018,8(1):6275. <https://doi.org/10.1038/s41598-018-24689-1>
72. Shakirov R.B., Syrbu N.S., Obzhairov A.I. Isotope-gas-geochemical features of methane and carbon dioxide distribution on Sakhalin Island and the adjacent shelf of the Sea of Okhotsk. *Vestnik KRAUNTS. Nauki o Zemle = Bull. of KRAESC. Earth Sciences*. 2012,2(20):100–113. (In Russ.). <https://www.elibrary.ru/pwrapz>
73. Ershov V.V. Mud volcanoes on the planet Earth: review of monograph «Atlas of the world mud volcanoes». *Geosistemy perekhodnykh zon = Geosystems of Transition Zones*. 2018,2(4):419–421. (In Russ.). <https://doi.org/10.30730/2541-8912.2018.2.4.419-421>
74. Istadi B.P., Wibowo H.T., Sunardi E., Hadi S., Sawolo N. Mud volcano and its evolution. In: I.A. Dar (ed.). *Earth Sciences*. Publ.: InTechOpen, 2012, p. 375–434. <https://doi.org/10.5772/24944>
75. Mazzini A., Svensen H., Akhmanov G.G., Aloisi G., Planke S., Malthé-Sørensen A., Istadi B. Triggering and dynamic evolution of the LUSI mud volcano, Indonesia. *Earth and Planetary Science Letters*. 2007,261(3-4):375–388. <https://doi.org/10.1016/j.epsl.2007.07.001>
76. Imposa S., Grassi S., De Guidi G., Battaglia F., Lanaia G., Scudero S. 3D subsoil model of the San Biagio ‘Salinelle’ mud volcanoes (Belpasso, Sicily) derived from geophysical surveys. *Surveys in Geophysics*. 2016,37(4):1117–1138. <https://doi.org/10.1007/s10712-016-9380-4>
77. Medialdea T., Somoza L., Pinheiro L.M., Fernandez-Puga M.C., Vazquez J.T., Lean R., Ivanov M.K., Magalhaes V., Diaz-del-Rio V., Vegas R. Tectonics and mud volcano development in the Gulf of Cadiz. *Marine Geology*. 2009,261(1):48–63. <https://doi.org/10.1016/j.margeo.2008.10.007>
78. Huguen C., Foucher J.P., Mascle J., Ondréas H., Thouement M., Gontharet S., Stadnitskaia A., Pierre C., Bayon G., et al. Menes caldera, a highly active site of brine seepage in the Eastern Mediterranean Sea: In situ observations from the NAUTINIL expedition (2003). *Marine Geology*. 2009,261(1-4):138–152. <http://dx.doi.org/10.1016/j.margeo.2009.02.005>
79. Robertson A.H.F., Kopf A. Tectonic setting and processes of mud volcanism on the Mediterranean Ridge accretionary complex: evidence from Leg 160. In: Robertson A.H.F. et al. (eds.) *Proceedings of the Ocean Drilling Program, Scientific Results*. 1998,160:665–680.
80. Yudin V.V. Mud volcanism in the Crimea Mountains. *Doklady: Reports of the Academy of Sciences*. 1995,341(3):395–398. (In Russ.).
81. Huguen C., Mascle J., Woodside J., Zitter T., Foucher J.P. Mud volcanoes and mud domes of the Central Mediterranean Ridge: near-bottom and in situ observations. *Deep-Sea Research. Part I*. 2005,52:1911–1931. <https://doi.org/10.1016/j.dsr.2005.05.006>
82. Kioka A., Ashi J., Sakaguchi A., Sato T., Muraoka S., Yamaguchi A., Hamamoto H., Wang K., Tokuyama H. Possible mechanism of mud volcanism at the prism-backstop contact in the western Mediterranean Ridge accretionary complex. *Marine Geology*. 2015,363:52–64. <http://dx.doi.org/10.1016/j.margeo.2015.01.014>
83. Somoza L., Diaz-del-Rio V., Leon R., Ivanov M., Fernandez-Puga M.C., Gardner J.M., Hernandez-Molina F.J., Pinheiro L.M., Rodero J., et al. Seabed morphology and hydrocarbon seepage in the Gulf of Cadiz mud volcano area: acoustic imagery, multibeam and ultra-high resolution seismic data. *Marine Geology*. 2003,195(1-4):153–176. [https://doi.org/10.1016/S0025-3227\(02\)00686-2](https://doi.org/10.1016/S0025-3227(02)00686-2)
84. Shelting S.K., Sheikov A.A., Prokoptseva S.V. [On the mechanisms of folding and mud volcanism formation in the Sorokin Trough]. *PRONEFT*. 2023,8(3):62–72 (In Russ.). <https://doi.org/10.51890/2587-7399-2023-8-3-62-72>
85. Reed D.L., Silver E.A., Tagudin J.E., Shipley T. H., Vrolijk P. Relations between mud volcanoes, thrust deformation, slope sedimentation, and gas hydrate, offshore north Panama. *Marine and Petroleum Geology*. 1990,7(1):44–54. doi:10.1016/0264-8172(90)90055-I
86. Ben-Avraham Z., Reshef M., Smith G. Seismic signature of gas hydrate and mud volcanoes of the South African continental margin. In: Martinelli G., Panahi B. (eds.) *Mud volcanoes, geodynamics and seismicity: NATO Science Series, Series IV: Earth and Environmental Series*. Dordrecht: Springer, 2005, 51, p.17–27.
87. Argentino C., Mattingsdal R., Eidvin T., Ohm S.E., Panier G. A constellation of mud volcanoes originated from a buried Arctic mega-slide, Southwestern Barents Sea. *Scientific Reports*. 2025,15(1):15161. <https://doi.org/10.1038/s41598-025-99578-5>
88. Riboulot V., Cattaneo A., Sultan N., Garziglia S., Ker S., Imbert P., Voisset M. Sea-level change and free gas occurrence influencing a submarine landslide and pockmark formation and distribution in deepwater Nigeria. *Earth and Planetary Science Letters*. 2013,375:78–91. <http://dx.doi.org/10.1016/j.epsl.2013.05.013>
89. Khlystov O.M., Poort J., Mazzini A., Akhmanov G.G., Minami H., Hachikubo A., Khabuev A.V., Kazakov A.V., De Batist M., et al. Shallow-rooted mud volcanism in Lake Baikal. *Marine and Petroleum Geology*. 2019,102:580–589. <https://doi.org/10.1016/j.marpetgeo.2019.01.005>

90. Belyaeva A.A., Akhmanov G.G., Korost S.R., Khlystov O.M. [Composition and structure of mud volcanic deposits of the Bolshoy mud volcano (Lake Baikal)]. In: *Marine Research and Education: (MARESEDU-2017): Proceedings of the VI International Scientific and Practical Conference, Moscow, 2017*. Tver: PoliPRESS, 2017, p. 292–293. (In Russ.). <https://www.elibrary.ru/ypcyyk>
91. Batist M.De, Rensbergen P.V., Vanneste M., Poort J., Klerkx J., Golmshtok A.Y., Kremlev A.N., Khlystov O.M., Krinitsky P. Active hydrate destabilization in Lake Baikal, Siberia? *Terra Nova*. 2002,14(6):436–442. <https://doi.org/10.1046/j.1365-3121.2002.00449.x>
92. Rensbergen P.V., Batist M.De, Klerkx J., Hus R., Poort J., Vanneste M., Granin N., Khlystov O., Krinitsky P. Sublacustrine mud volcanoes and methane seeps caused by dissociation of gas hydrates in Lake Baikal. *Geology*. 2002,30:631–634. [https://doi.org/10.1130/0091-7613\(2002\)030<0631:SMVAMS>2.0.CO;2](https://doi.org/10.1130/0091-7613(2002)030<0631:SMVAMS>2.0.CO;2)
93. Bogdanov A.A., Vidishcheva O.N., Ryazantseva K.Yu., Nemchenko N.V., Akhmanov G.G., Solovieva M.A. [Results of the study of hydrocarbon gases and organic matter in the bottom sediments of the MSU mud volcano during the Class@Baikal-2022 expedition]. In: *Морские исследования и образование (MARESEDU-2022): Труды XI Междунар. науч.-практ. конф., Москва, 2022*. Tver: PoliPRESS, 2022, p. 171–174. (In Russ.). <https://www.elibrary.ru/cdzfdw>
94. Pyatilova A.M., Akhmanov G.G., Solovieva M.A., Khlystov O.M. [Mud volcanoes of Lake Baikal (based on Class@Baikal materials)]. In: *Marine Research and Education (MARESEDU-2022): Proceedings of the XI International Scientific and Practical Conference, Moscow, 2022*. Tver: PoliPRESS, 2022, p. 41–44. (In Russ.). <https://www.elibrary.ru/agpfgw>
95. Xing Ju., Spiess V. Shallow gas transport and reservoirs in the vicinity of deeply rooted mud volcanoes in the central Black Sea. *Marine Geology*. 2015,369:67–78. <https://doi.org/10.1016/j.margeo.2015.08.005>
96. Ivanov M., Mazzini A., Blinova V., Kozlova E., Laberg J.-S., Matveeva T., Taviani M., Kaskov N. Seep mounds on the Southern Vøring Plateau (offshore Norway). *Marine and Petroleum Geology*. 2010,27(6):1235–1261. <https://doi.org/10.1016/j.marpetgeo.2009.11.009>
97. Fryer P., Wheat C.G., Mottl M.J. Mariana blueschist mud volcanism: implications for conditions within the subduction zone. *Geology*. 1999,27(2):103–106. [https://doi.org/10.1130/0091-7613\(1999\)027<0103:MBMVIF>2.3.CO;2](https://doi.org/10.1130/0091-7613(1999)027<0103:MBMVIF>2.3.CO;2)
98. Fryer P. Serpentinite mud volcanism: Observations, processes, and implications. *Annual Review of Marine Science*. 2012,4(1):345–373. <https://doi.org/10.1146/annurev-marine-120710-100922>
99. Savov I.P., Ryan J.G., D'Antonio M., Fryer P. Shallow slab fluid release across and along the Mariana arc-basin system: insights from geochemistry of serpentinized peridotites from the Mariana fore arc. *Journal of Geophysical Research*. 2007,112(B9):B09205. <https://doi.org/10.1029/2006JB004749>
100. Wheat C.G., Fryer P., Fisher A.T., Hulme S., Jannasch H., Mottl M.J., Becker K. Borehole observations of fluid flow from South Chamorro Seamount, an active serpentinite mud volcano in the Mariana forearc. *Earth and Planetary Science Letters*. 2008,267(3):401–409. <https://doi.org/10.1016/j.epsl.2007.11.057>
101. Napoli S., Spatola D., Casalbore D., Lombardo L., Tanyas H., Chiocci F.L. Comprehensive global inventory of submarine mud volcanoes. *Scientific Data*. 2025,12(1):382. <https://doi.org/10.1038/s41597-025-04726-1>
102. Bogoyavlensky V.I., Bogoyavlensky I.V., Kishankov A.V. Geophysical methods of ensuring technological sovereignty and national security of Russia in the Arctic. *Herald of the Russian Academy of Sciences*. 2024,94(10):32–46. doi:10.31857/S0869587324100055; <https://elibrary.ru/ervsfe>
103. Mironyuk S.G., Kolyubakin A.A., Golenok O.A., Roslyakov A.G., Terekhova Ya.E., Tokarev M.Y. [Mud volcanic structures (volcanoids) of the Kara Sea: morphological features and structure]. In: *Geology of seas and oceans: Proceedings of XXII International Conference on marine geology*. Moscow: IO RAS, 2019, 5, p. 192–196. (In Russ.). <https://doi.org/10.29006/978-5-9901449-9-6.ICMG-2019-5>
104. Bogoyavlensky V.I. Fundamental aspects of the catastrophic gas blowout genesis and the formation of giant craters in the Arctic. *Arctic: Ecology and Economy*. 2021,11(1):51–66. (In Russ.). <https://doi.org/10.25283/2223-4594-2021-1-51-66>
105. Bogoyavlensky V.I., Bogoyavlensky I.V., Kishankov A.V., Kazanin A.G. New information on subaqueous permafrost, gas hydrates and explosive degassing of the Earth on shelf and on land of the Arctic. In: *Geology of seas and oceans: Proceedings of XXVI International Conference on marine geology*. Moscow: IO RAS, 2025, 1, p. 47–51. (In Russ.). <https://doi.org/10.29006/978-5-6051054-7-3>
106. Andreassen K., Hubbard A., Winsborrow M., Patton H., Vadakkepuliambatta S., Plaza-Faverola A., Gudlaugsson E., Serov P., Deryabin A., et al. Massive blow-out craters formed by hydrate-controlled methane expulsion from the Arctic seafloor. *Science*. 2017,356(6341):948–953. <https://doi.org/10.1126/science.aal4500>
107. Solheim A., Elverhøi A. Gas-related sea floor craters in the Barents Sea. *Geo-Marine Letters*. 1993,13(4):235–243. <https://doi.org/10.1007/bf01207753>
108. Waage M., Serov P., Andreassen K., Waghorn K.A., Bünz S. Geological controls of giant crater development on the Arctic seafloor. *Scientific Reports*. 2020,10(1):8450. <https://doi.org/10.1038/s41598-020-65018-9>
109. Somoza L., Leon R., Medialdea T., Perez L.F., Gonzalez F.J., Maldonado A. Seafloor mounds, craters and depressions linked to seismic chimneys breaching fossilized diagenetic bottom simulating reflectors in the central and southern Scotia Sea, Antarctica. *Global and Planetary Change*. 2014,123:359–373. <https://doi.org/10.1016/j.gloplacha.2014.08.004>
110. Hensen C., Scholz F., Nuzzo M., Valadares V., Gràcia E., Terrinha P., Liebetrau V., Kaul N., Silva S., et al. Strike-slip faults mediate the rise of crustal-derived fluids and mud volcanism in the deep sea. *Geology*. 2015,43(4):339–342. <https://doi.org/10.1130/G36359.1>
111. Lomtev V.L., Il'ev A.Ya., Gurinov M.G. New data about Magellan Seamounts structure (East Mariana Basin, SW Pacific). *Lithosphere*. 2007,6:125–136. (In Russ.). <https://www.elibrary.ru/jvyrnz>
112. Tatarinov A.V., Yalovik L.I., Kanakin S.V. The generation and mineral associations of rock assemblages at mud volcanoes: Southeastern Siberia. *Journal of Volcanology and Seismology*. 2016,10(4):248–262. <https://doi.org/10.1134/S0742046316030052>
113. Panieri G., Argentino C., Savini A., Ferré B., Hemmateenejad F., Eilertsen M.H., Mattingdal R., Ramalho S.P., Eidvin T., et al. Sanctuary for vulnerable Arctic species at the Borealis Mud Volcano. *Nature Communications*. 2025,16(1):1–11. <https://doi.org/10.1038/s41467-024-55712-x>