Element signatures and lichens: A historical perspective in air pollution studies

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&

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Lichen Matters

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Our talk Today

- **Background**
  - Lichens and Biomonitoring
- **Biomonitoring element deposition across Point Sources (local scale) / historical collections**
  - Biogeochemical aspects
  - Transboundary influences
- **Conclusions**
  - Rare elements
  - Conservation
  - Science Outreach

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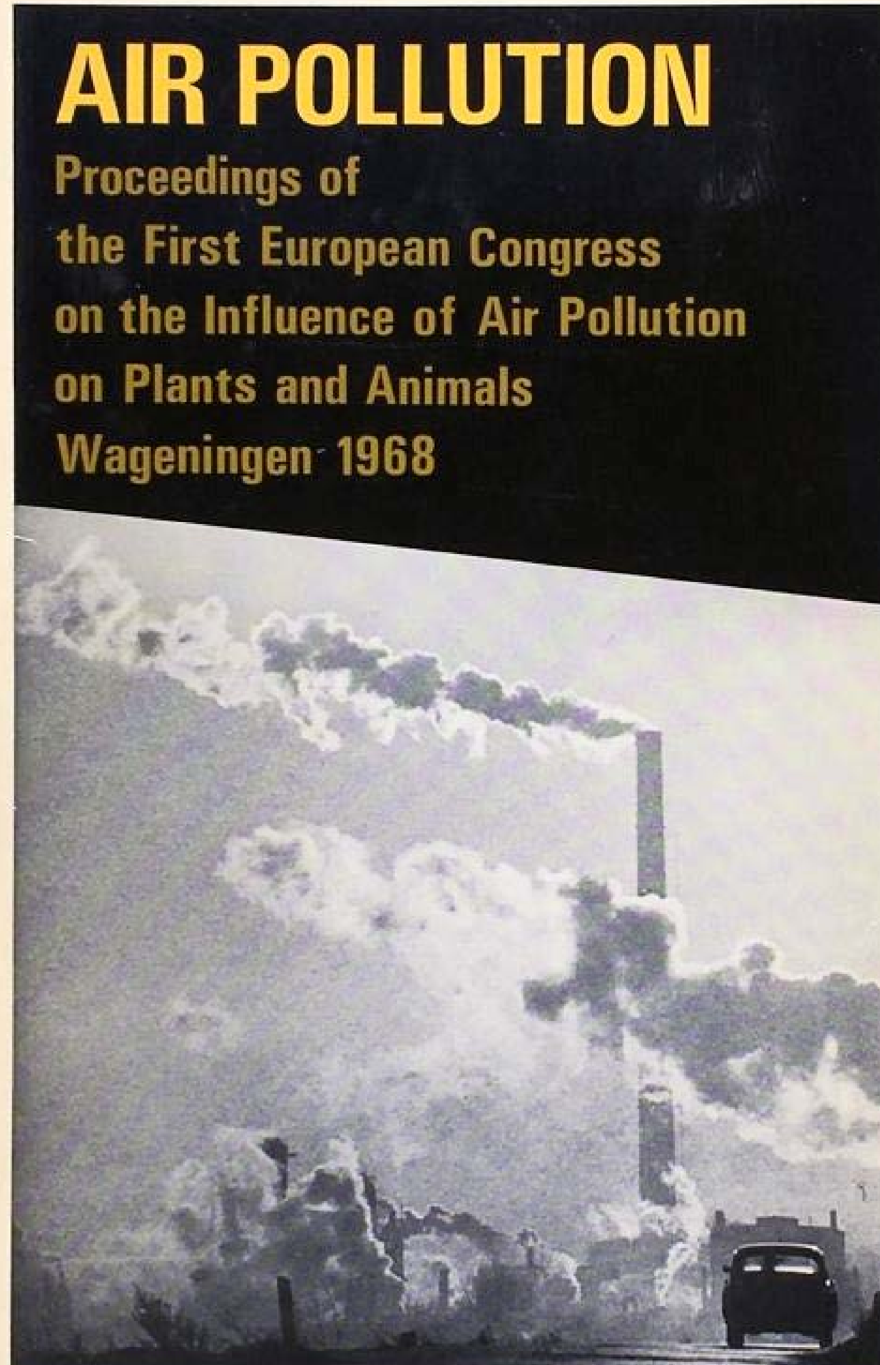
Background

50 Years since ….

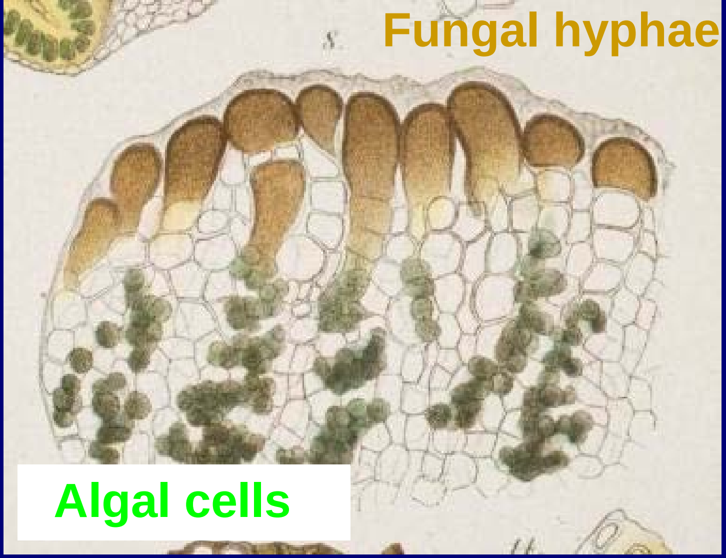
'It has been widely assumed that the highly efficient mechanism which lichens and bryophytes possess for accumulating a wide range of substances from very dilute solutions is, at least partly, responsible for their acute sensitivity to atmospheric SO_2' .

Specimens sampled nearest to Newcastle city centre contained much larger amounts of sulphur than did specimens sampled further away.

Gilbert, O.L. (1968) The effect of SO_2 on lichens and bryophytes around Newcastle upon Tyne. Proceedings of the First European Congress on the Influence of Air Pollution on Plants and Animals. Wageningen, April 22 to 27, 1968.

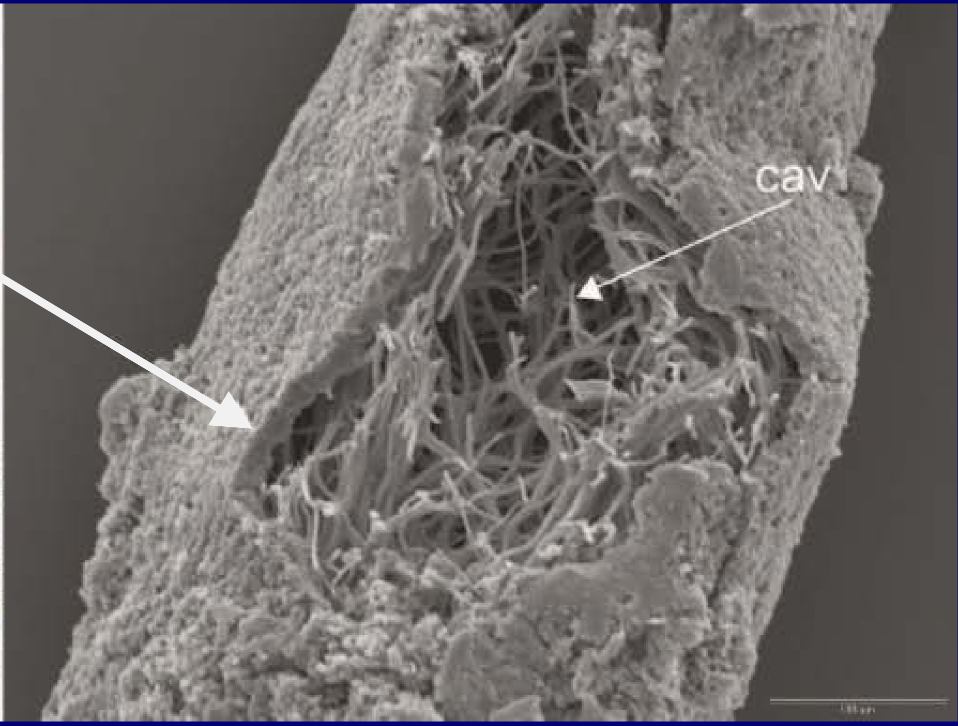


Lichens are symbioses involving fungi, algae and bacteria.



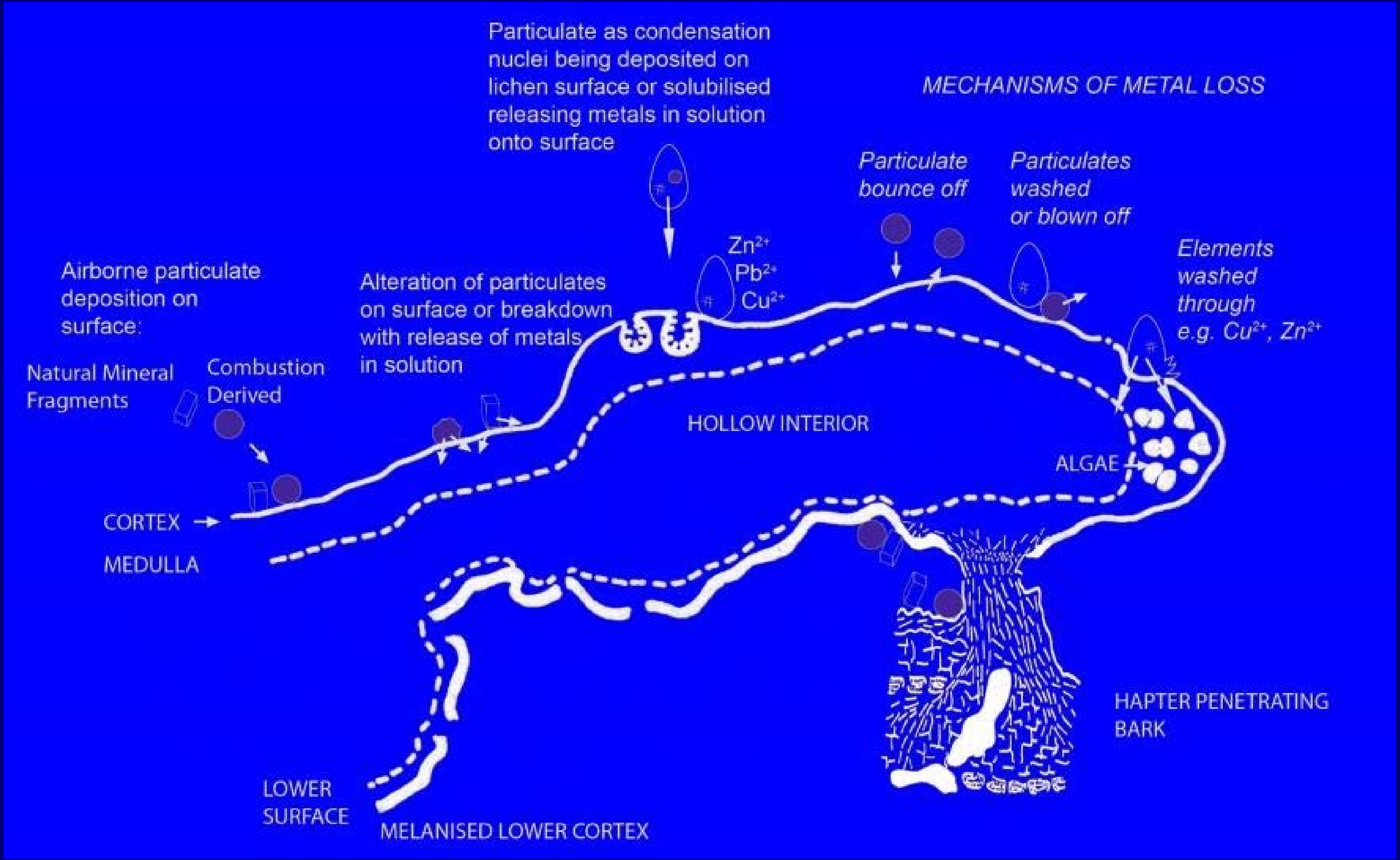
Schwendener, S. (1869) Die Algentypen der Flechtengonidien : Programm für Rectoratsfeier der Universität. Basel : Universitätsbuchdruckerei von C. Schultze.

Cortex in *Letharia vulpina* – a 'biofilm' of 3 different fungi



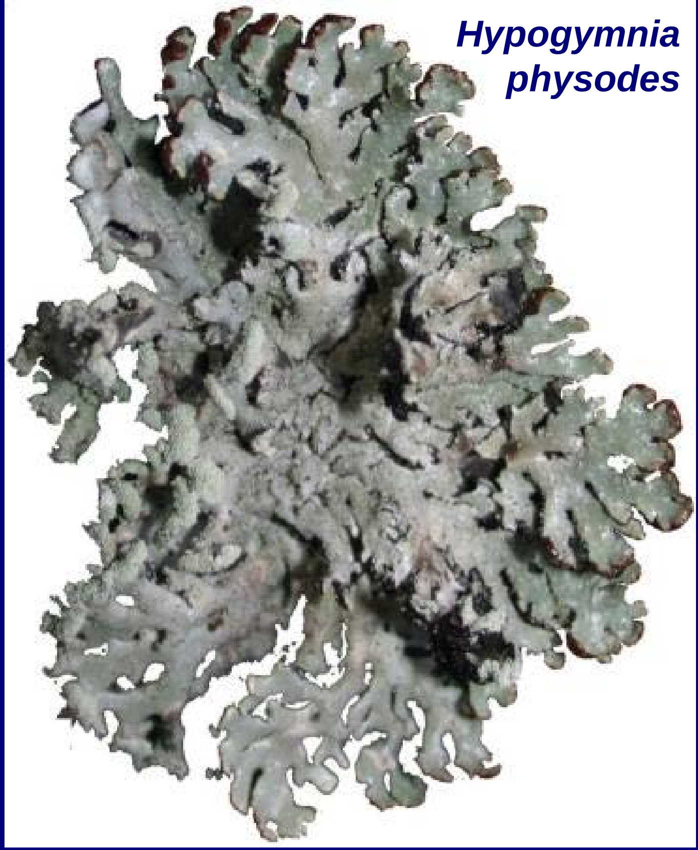
Spribille, T. (2018) Relative symbiont input and the lichen symbiotic outcome. *Current Opinion in Plant Biology* **44**: 57-63.

Diagrammatic representation of section of *Hypogymnia physodes* showing the main mechanisms by which metals may be deposited on or lost from surfaces



Purvis, O.W., Williamson, B.J., Spiro, B., Udachin, V., Mikhailova, I.N. & Dolgopolova, A. (2013) Lichen monitoring as a potential tool in environmental forensics: case study of the Cu smelter and former mining town of Karabash, Russia. In: D., Ruffell, A. & Dawson, L. A. (eds) *Environmental and Criminal Geoforensics*. Geological Society, London, Special Publications 384: 133-146. http://dx.doi.org/10.1144/SP384.6

GROWTH FORMS



FOLIOSE

FRUTICOSE

Foliose and fruticose forms frequently used to assess spatial and temporal patterns of element deposition.

Saxicolous crustose lichens more likely influenced by mineral components in the substrate.

CRUSTOSE

Myriospora signyensis **Purvis, Fdez-Brime, M. Westb. & Wedin**

Some References

Balabanova, B. Stafilov, T. Šajn, R. & Baèeva, K. (2012) Characterisation of heavy metals in lichen species *Hypogymnia physodes* and *Evernia prunastri* due to biomonitoring of air pollution in the vicinity of copper mine*. International Journal of Environmental Research* 6: 779-792

Bolshunova, T., L. Rikhvanov & Mezhibor, A. (2016) Assessment of the tailing impact on the environment according to the study of epiphytic lichens. The case of Komsomolsk and Ursk tailings, Kemerovo region, Russia). in *16th International Multidisciplinary Scientific GeoConference: Ecology, Economics, Education and Legislation, SGEM 2016*. 2016. International Multidisciplinary Scientific Geoconference.

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Mezhibor, A.M., T.S. Bolshunova & Rikhvanov, L.P. (2016) Geochemical features of sphagnum mosses and epiphytic lichens in oil and gas exploitation areas (the case of Western Siberia, Russia). *Environmental Earth Sciences*, 75: 9.

Rusu, A.M., Jones, G.C., Chimonides, P.D.J. & Purvis, O.W. (2006) Biomonitoring using the lichen Hypogymnia physodes and bark samples near Zlatna, Romania immediately following closure of a copper ore-processing plant. *Environmental Pollution* 143: 81-88.

Pollard, A.S., Williamson, B.J., Taylor, M., Purvis, O.W., Goossens, M., Reis, S., Aminov, P., Udachin, V., & Osborne, N. (2015) Integrating dispersion modelling and lichen sampling to assess harmful heavy metal pollution around the Karabash copper smelter, Russian Federation. *Atmospheric Pollution Research* 6: 939-945.

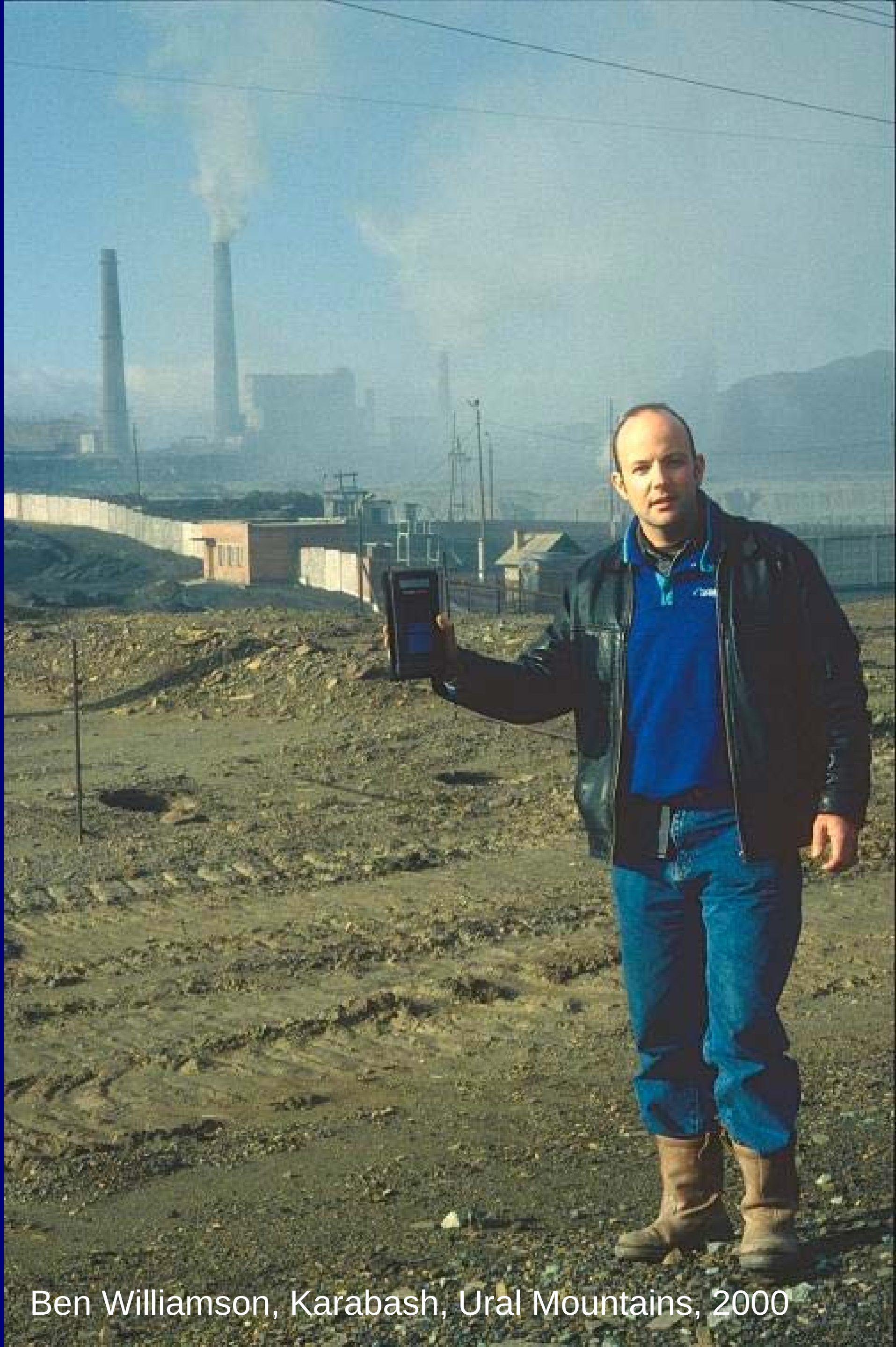
Purvis, O.W., Chimonides, P. J., Jones, G. C., Mikhailova, I. N., Spiro, B., Weiss, D. J. & Williamson, B. J. (2004) Lichen biomonitoring near Karabash Smelter Town, Ural Mountains, Russia, one of the most polluted areas in the world*. Proceedings of the Royal Society B: Biological Sciences* 271: 221-226.

Purvis, O.W. (2010) Chapter 3. Lichens and Industrial Pollution, in Ecology of Industrial Pollution, L.C. Batty and K. Hallberg, Editors. Cambridge University Press: Cambridge. p. 41-69.

Biomonitoring element deposition across Point Sources (local scale) with reference to historical collections

Point sources are Natural laboratories to refine biomonitoring methods and to assess the effects of pollutants and geology on biota

Mikhailova, I. & Vorobeichik, E.L. (1995) Epiphytic lichenosynusia under conditions of chemical pollution: dose-effect dependencies. *Russian Journal of Ecology* 26: 425-431.
Bell, J.N.B. & Treshow, M. (2002) Air Pollution and Plant Life. 2nd ed., Chichester: Wiley. xi, 465.
Rusu, A.-M., P.D.J. Chimonides, G.C. Jones, R. Garcia-Sanchez & Purvis, O.W. (2006) Multi-element including rare earth content of lichens, bark, soils, and waste following industrial closure. *Environmental Science & Technology* **40**: 4599-4604
Purvis, O.W. (2010) Chapter 3. Lichens and Industrial Pollution, in Ecology of Industrial Pollution, L.C. Batty and K. Hallberg, Editors. Cambridge University Press: Cambridge. p. 41-69.



Ben Williamson, Karabash, Ural Mountains, 2000

Biomonitoring particulate deposition in the Urals

"TAPM", an atmospheric transport model, to simulate near-source atmospheric transport and dry deposition of particulate matter-bound metal emissions around Karabash smelter

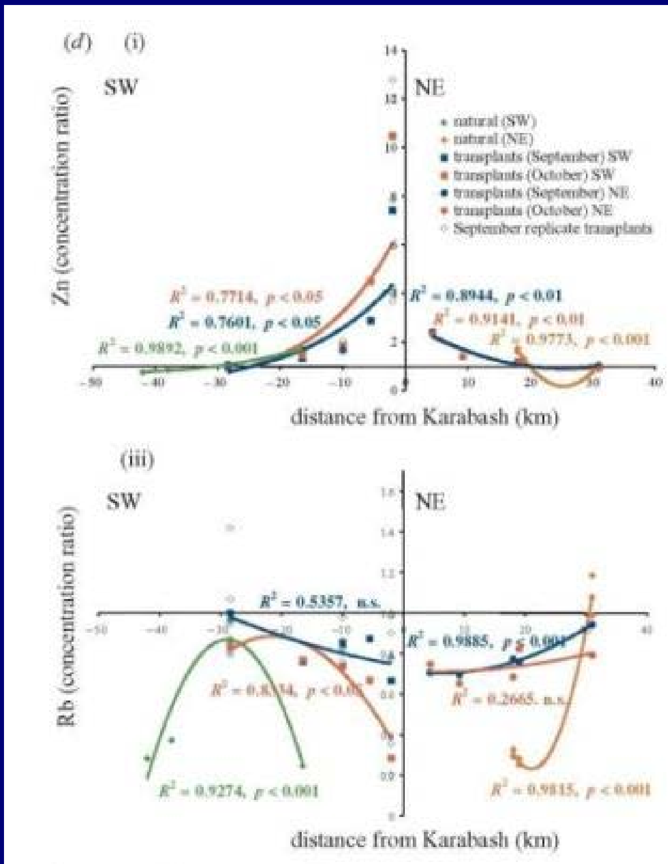
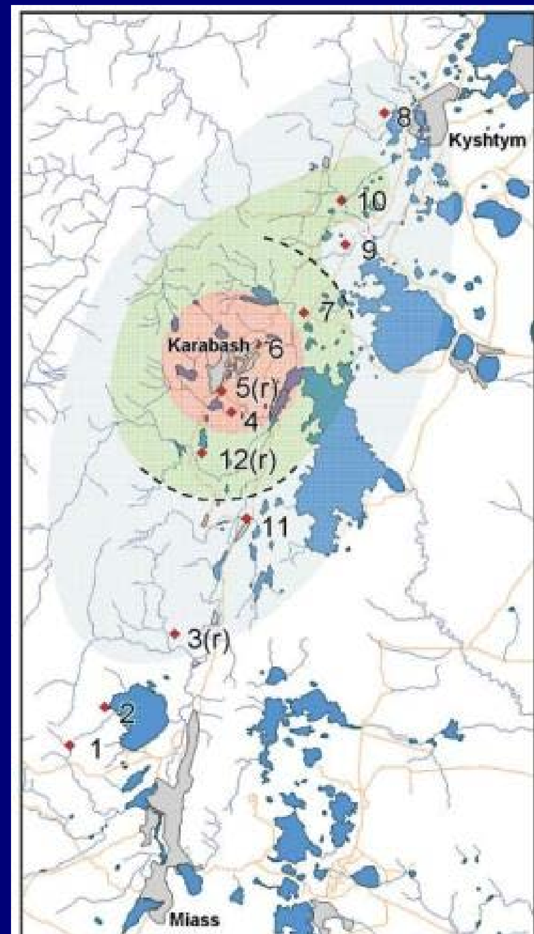
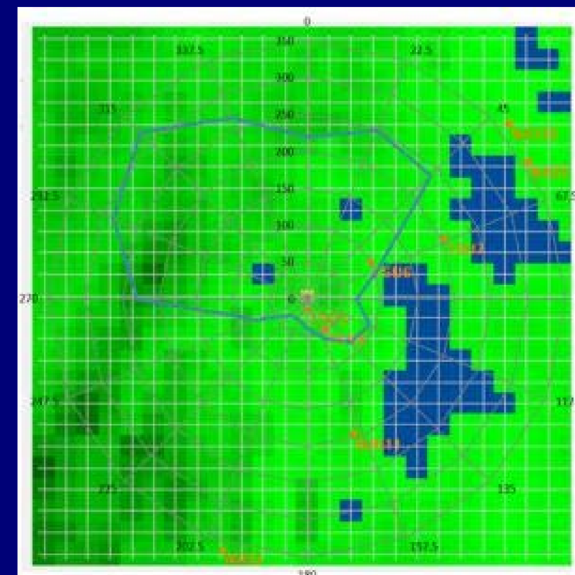


Figure 2. (Caption overleaf.)





TAPM modelling is in agreement with previous studies that smelter emissions are the major source of environmental Pb deposition around Karabash. Further work is required to determine whether the Pb in the lichens is largely sourced from current smelter airborne emissions or windblown soil particles containing historic additions of Pb.

Mikhailova, I. & Vorobeichik, E.L. (1995) Epiphytic lichenosynusia under conditions of chemical pollution: dose-effect dependencies. *Russian Journal of Ecology* **26**: 425-431.

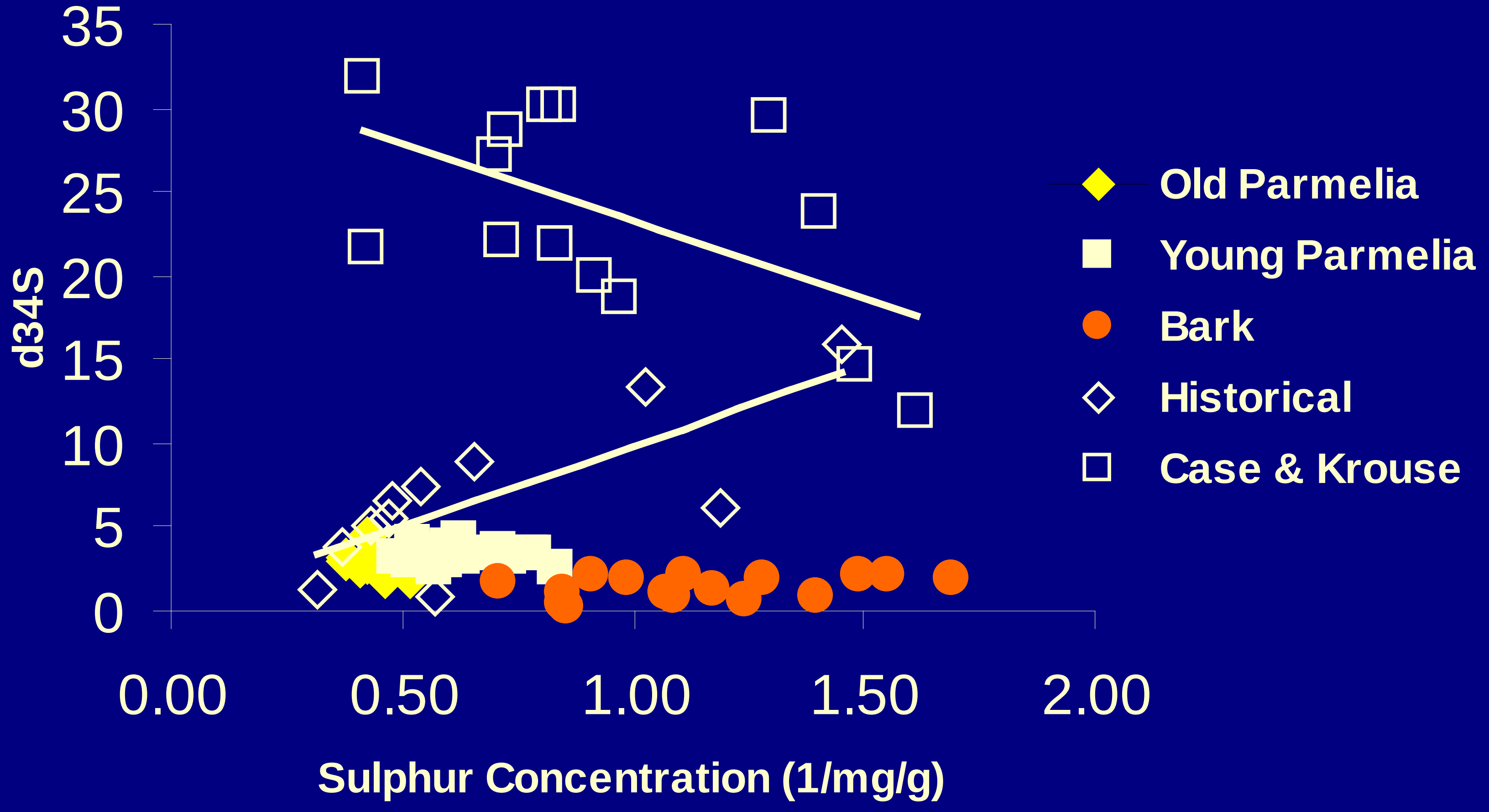
Haugland, T., Steinnes, E. & Frontasyeva, M. V. (2002) Trace metals in soil and plants subjected to strong chemical pollution. *Water Air Soil Pollut*. **137**, 343–353.

Frontasyeva, M.V., Frontasyeva, M. V., Smirnov, L. I., Steinnes, E., Lyapunov, S. M., & Cherchintsev, V. D. (2004) Heavy metal atmospheric deposition study in the South Ural Mountains. *J. Radioanal. Nucl. Chem*. **259**: 19-26.

Purvis, O. W., Chimonides, P. J., Jones, G. C., Mikhailova, I. N., Spiro, B., Weiss, D. J. & Williamson, B. J. (2004) Lichen biomonitoring near Karabash Smelter Town, Ural Mountains, Russia, one of the most polluted areas in the world. *Proceedings of the Royal Society of London Series B-Biological Sciences* **271:** 221-226.

Pollard, A.S., Williamson, B.J., Taylor, M., Purvis, O.W., Goossens, M., Reis, S., Aminov, P., Udachin, V., & Osborne, N. (2015) Integrating dispersion modelling and lichen sampling to assess harmful heavy metal pollution around the Karabash copper smelter, Russian Federation. *Atmospheric Pollution Research* **6:** 939-945.

Through analyzing variations in d34S content, sources of Sulphur can be determined



Spiro, B., Morrisson, J. & Purvis, O. W. (2002) Sulphur isotopes in lichens as indicators of sources. In *Monitoring with Lichens - Monitoring Lichens*, Nimis, P. L., Scheidegger, C., Wolseley, P., Eds. Kluwer: Dordrecht, pp 311-315 .

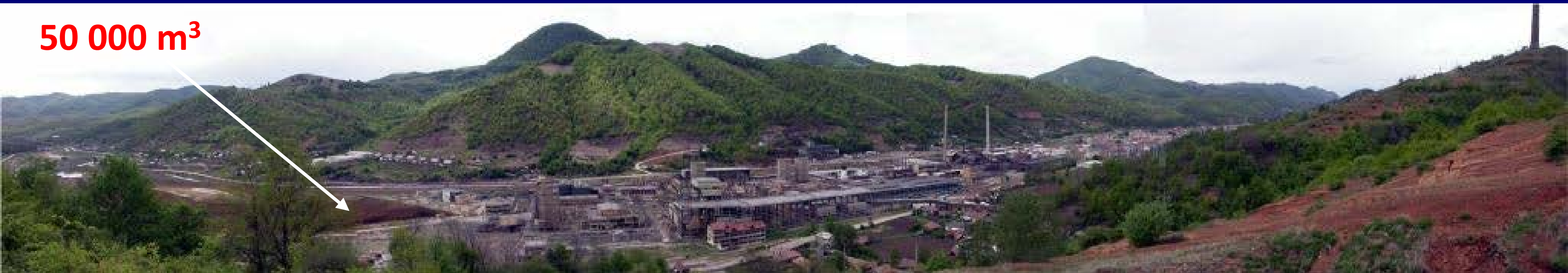
Purvis, O.W., Chimonides, J., Din, V.K., Erotokritou, L., Jeffries, T., Jones, G.C., Louwoff, S., Read, H. & Spiro, B. (2003) Which factors are responsible for the changing lichen floras of London? *Science of the Total Environment* **310**: 179-189.

Multi-element analysis of historical lichen collections help interpret past deposition scenarios

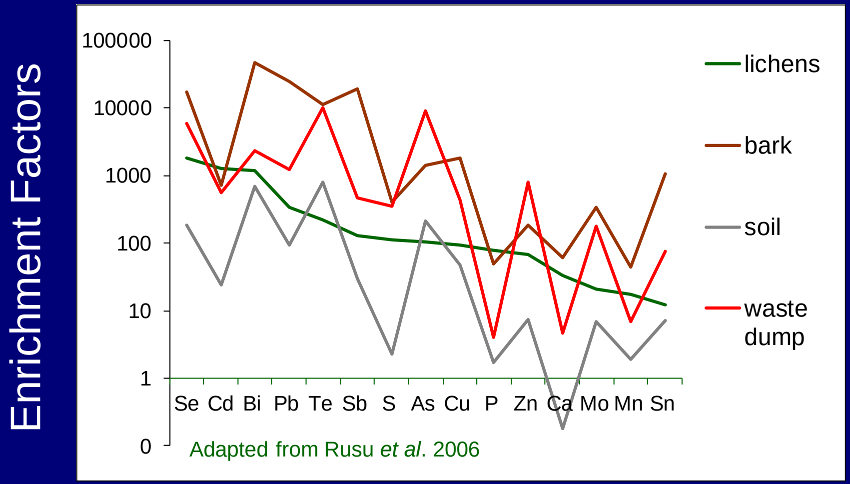
Parmelia sampled east and downwind of London at a farm during peak SO_2 emissions in 1967 contained highest V, Ni, Zn, Cd, Se, Ge contents, supporting derivation from fuel combustion; the same sample previously determined as having a low d34S and high S and N contents.

Purvis, O.W., Chimonides, P.D.J., Jeffries, T.E., Jones, G.C., Rusu, A.-M. & Read, H. (2007) Multi-element composition of historical lichen collections and bark samples, indicators of changing atmospheric conditions. *Atmospheric Environment* **41**: 72-80

Transboundary Pollution: Evidence from Romania & Norway



Zlatna town **two weeks** following smelter closure with major waste dump surrounded by semi-natural vegetation (Rusu *et al.* 2006)



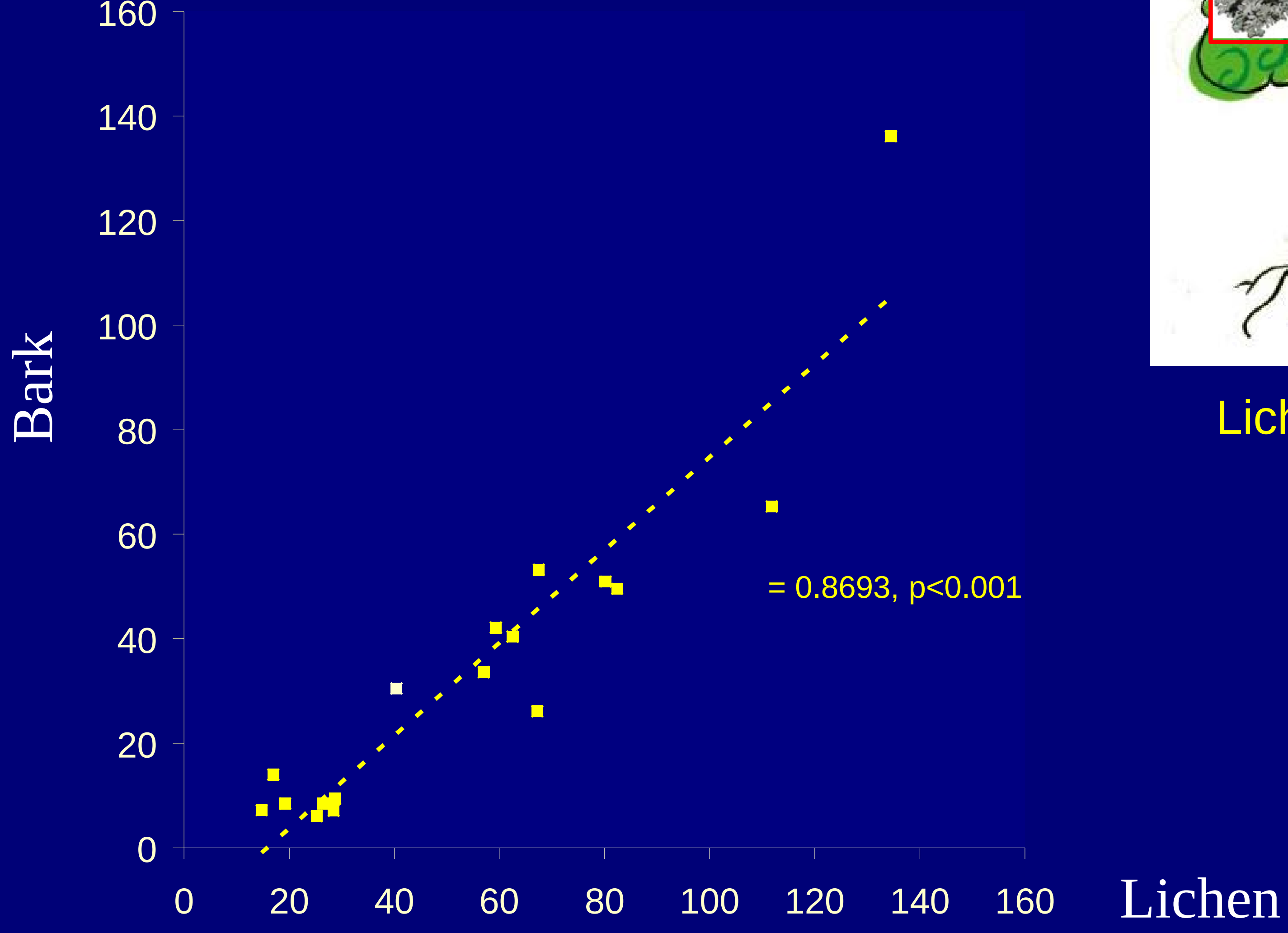
Complex geology with extensive hydrothermal Cu, Pb, Zn and Au deposits

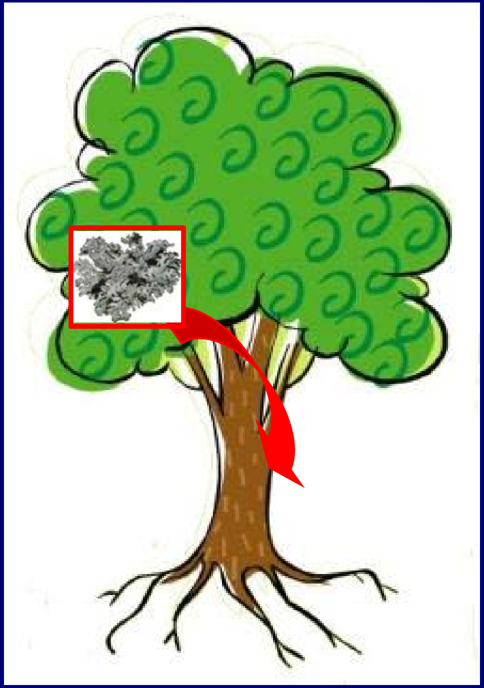
ABOVE LEFT: Enrichment factors for top 15 elements arranged in descending order (as recorded in lichens) compared with those in bark, soil, and waste dump samples normalized to upper continental crust with Sc.

Large-scale moss biomonitoring by Steinnes and co-workers identified higher Cd, Bi, Pb, Te, Sb, As, Zn, Mo, and Sn deposition in southern Norway attributed to long-range atmospheric transport (transboundary pollution)

Berg, T. & Steinnes, E. (1997) Recent trends in atmospheric deposition of trace elements in Norway as evident from the 1995 moss survey. *Sci Total Environ*. **208**: 197-206.
Steinnes, E. (2001) Metal contamination of the natural environment in Norway from long-range atmospheric transport. *Water Air Soil Pollut*. **1**: 449-460
Rusu, A.-M., P.D.J. Chimonides, G.C. Jones, R. Garcia-Sanchez & Purvis, O.W. (2006) Multi-element including rare earth content of lichens, bark, soils, and waste following industrial closure. *Environmental Science & Technology* **40**: 4599-4604.

Element Cycling [Mn/Ca ratios]

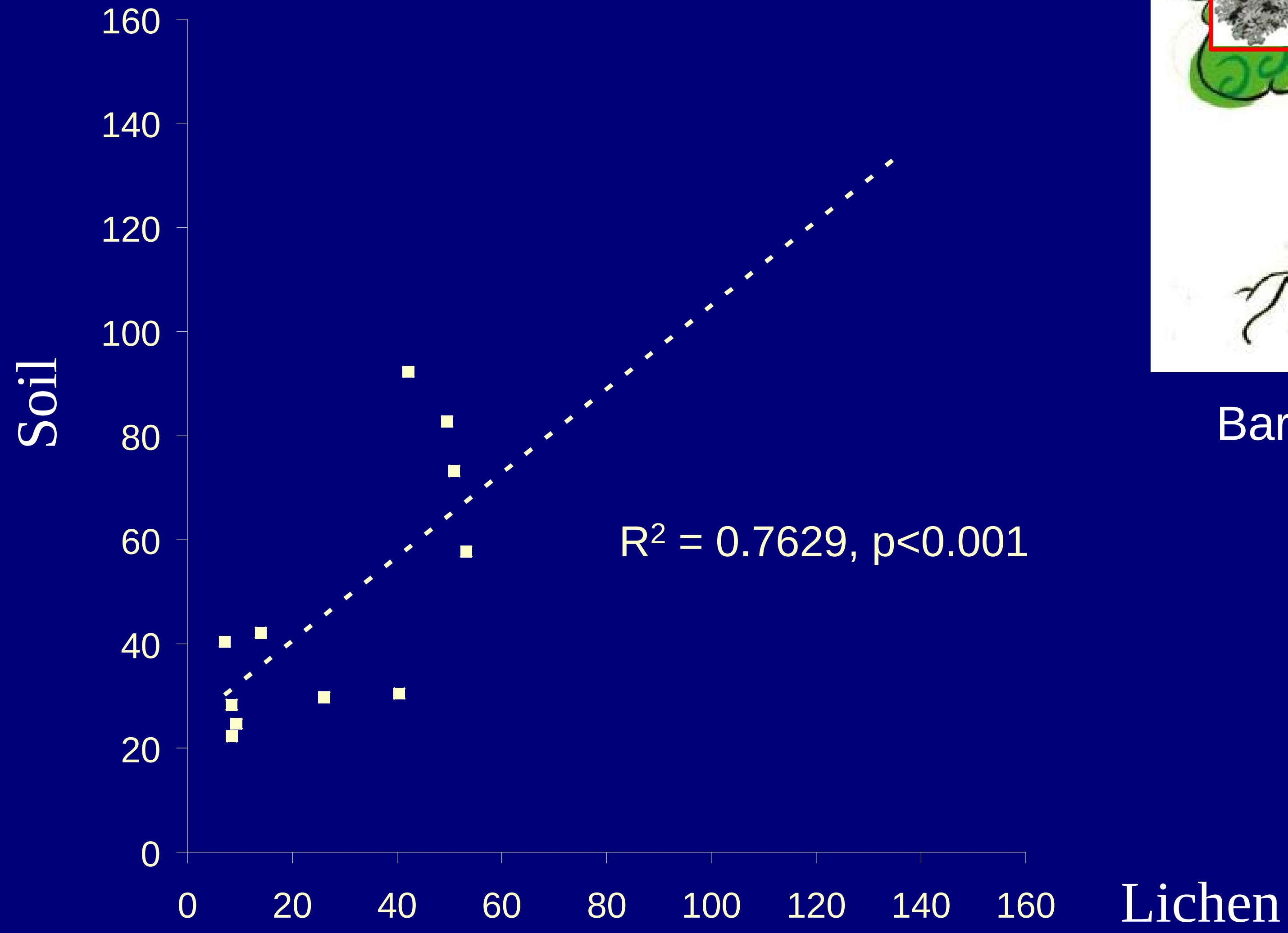


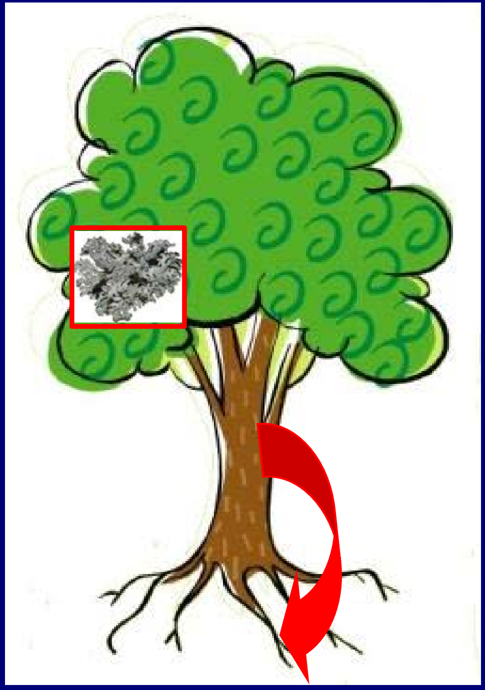


Lichen vs Bark

Purvis, O. W., Dubbin, W., Chimonides, P. D. J., Jones, G. C. & Read, H. (2008) The multi-element content of the lichen *Parmelia sulcata*, the soil and bark in relation to acidification and climate. *The Science of The Total Environment* **390**: 558-568.

Element Cycling [Mn/Ca ratios]

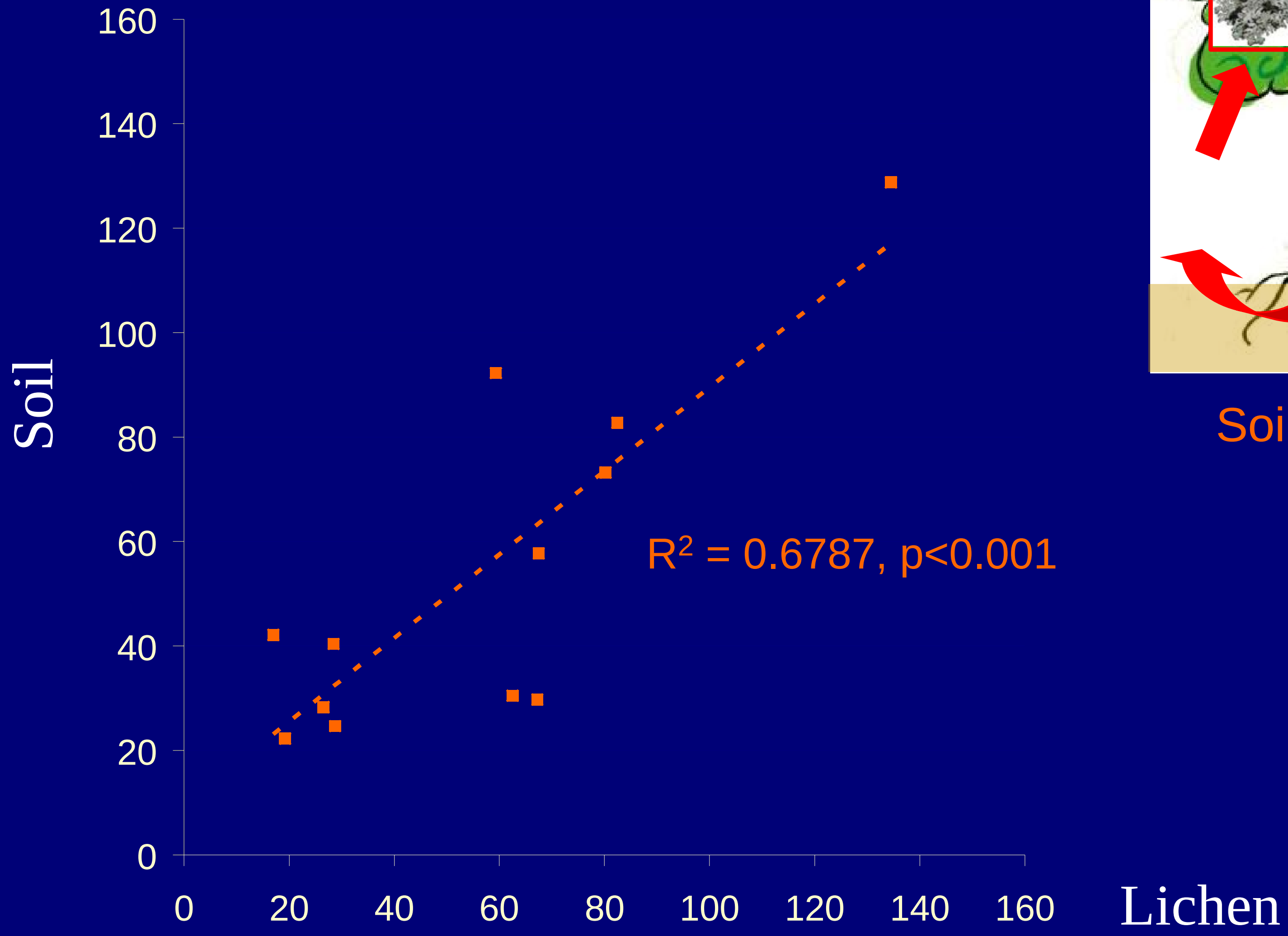


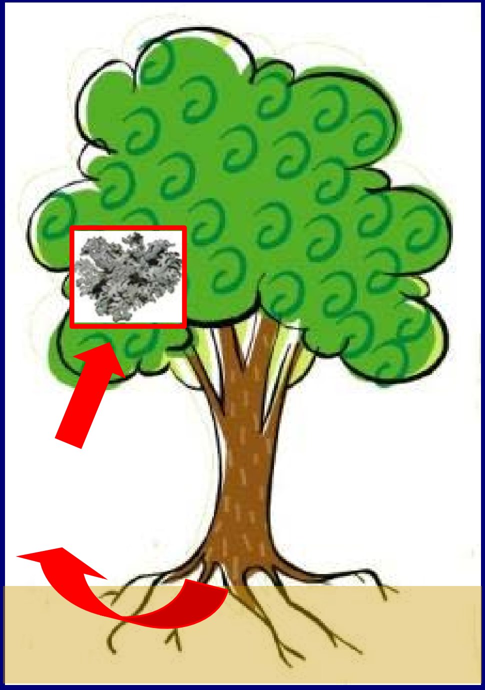


Bark vs Soil

Purvis, O. W., Dubbin, W., Chimonides, P. D. J., Jones, G. C. & Read, H. (2008) The multi-element content of the lichen *Parmelia sulcata*, the soil and bark in relation to acidification and climate. *The Science of The Total Environment* **390**: 558-568.

Element Cycling [Mn/Ca ratios]

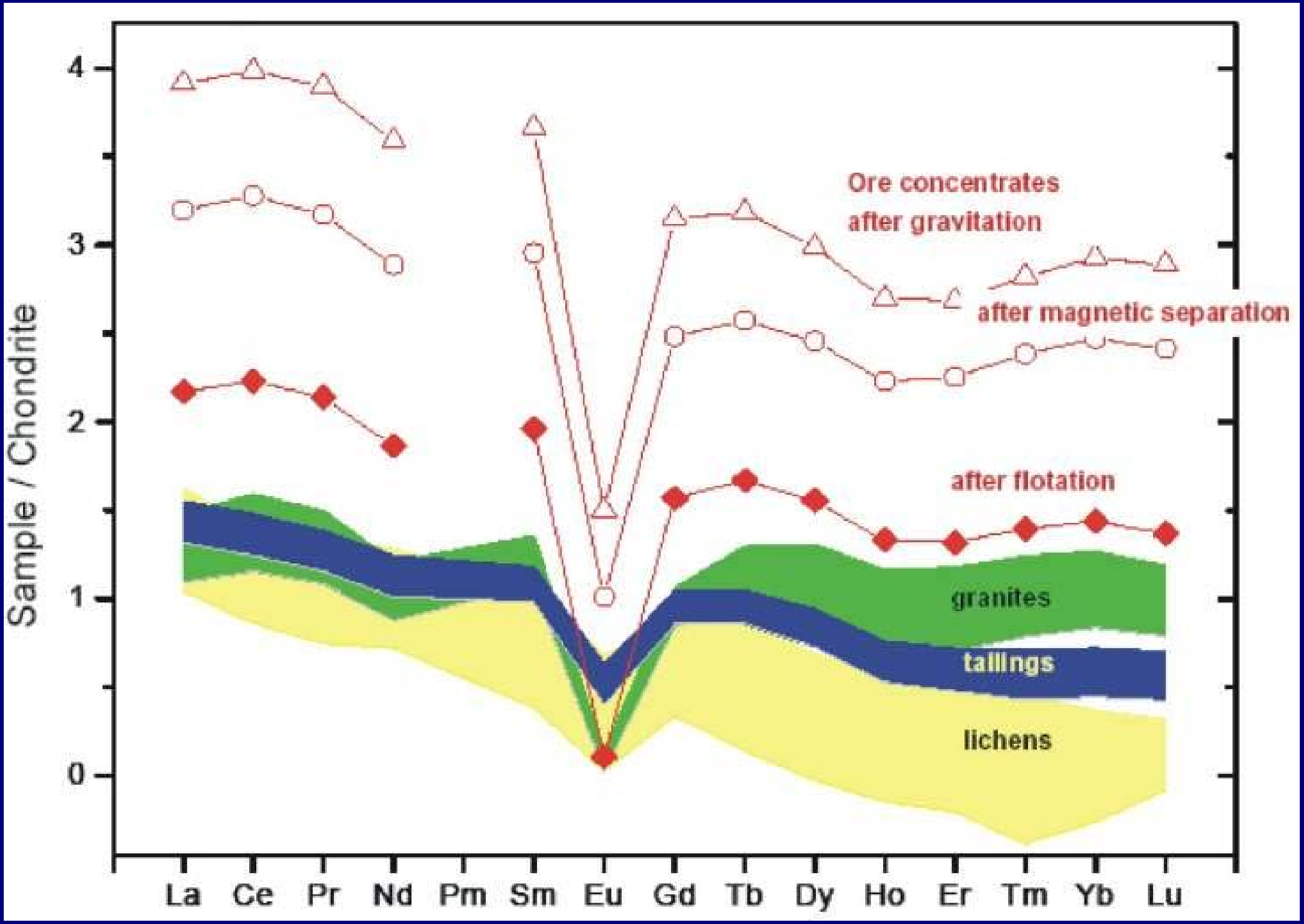




Soil vs Lichen

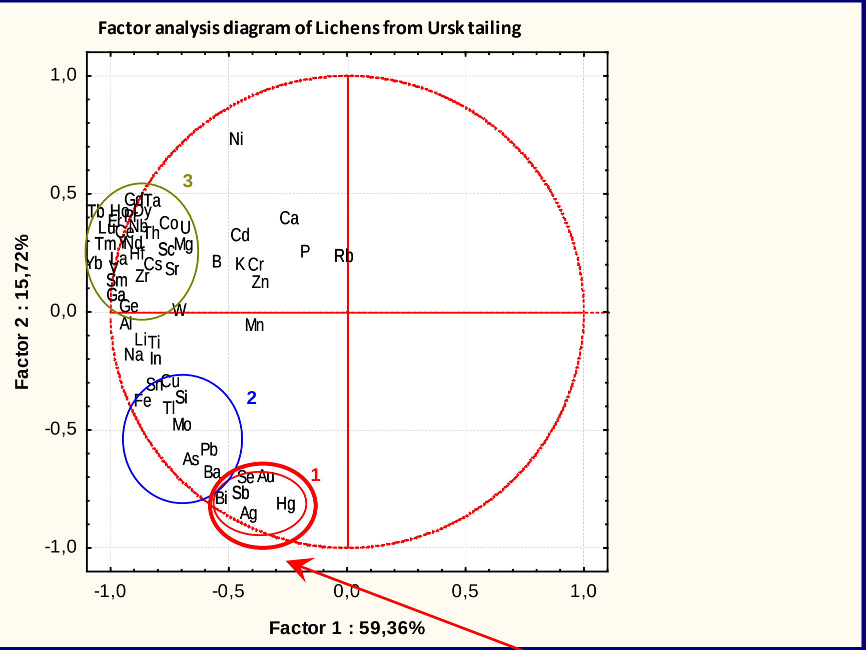
Purvis, O. W., Dubbin, W., Chimonides, P. D. J., Jones, G. C. & Read, H. (2008) The multi-element content of the lichen *Parmelia sulcata*, the soil and bark in relation to acidification and climate. *The Science of The Total Environment* **390**: 558-568.

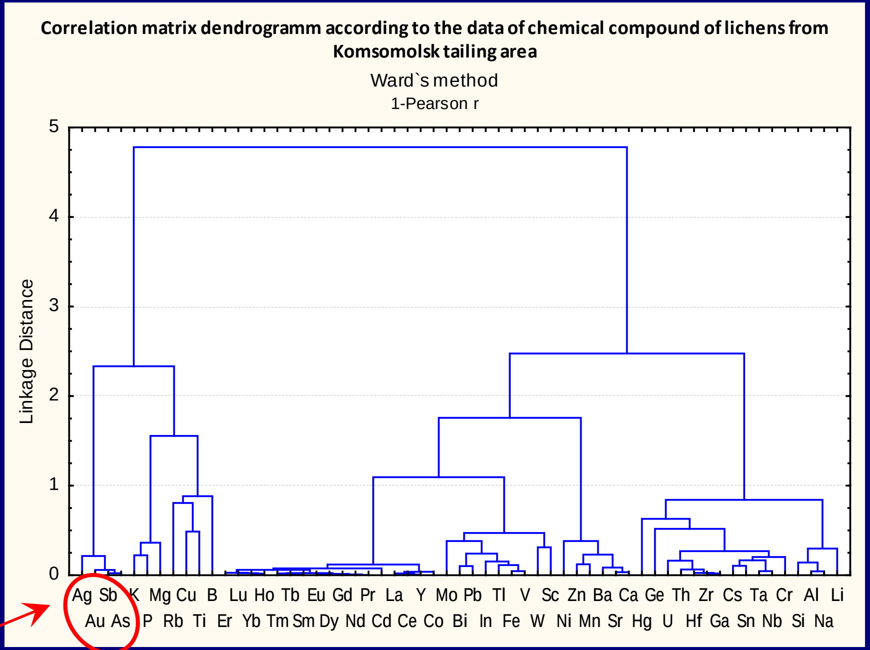
Rare Earth Element Patterns (REE) in lichens as source indicators



Dolgopolova, A., Weiss, D. J., Seltmann, R. & Dulski, P. (2006) Dust dispersal and Pb enrichment at the rare-metal Orlovka–Spokoinoe mining and ore processing site: Insights from REE patterns and elemental ratios *Journal of Hazardous Materials* **132**: 90–97.

Lichen biomonitoring near Ursk and Komsomolsk mine tailings (Kemerovo region) identified As, Cd, Sb, Hg, Au fixation in *Hypogymnia physodes* / *Evernia divaricata* from soil-dust aerosol deposition





Origin: Tailing Waste

Bolshunova, T.B. & Rikhvanova, L. (2016) Lichen Biomonitoring on the territory of tailings ponds of mining company (the case of Kemerovo Region). *Control and Monitoring* DOI: 10.12737/21719 [in Russian]

Conclusions

- **Biomonitoring rare elements hard to detect by conventional means**

Bolshunova, T.S., Baranovskaya, N.V., Dolgopolova, A., Kolesnikova, E.A., Mezhibor, A., Parygina, I.A., Rikhvanov, L.P., Yusupov, D.V. & Purvis. O.W. Biomonitoring using lichens near Ursk and Komsomolsk tailings (Kemerovo region), Russia

[For *Environmental Pollution*].

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Conclusions

- Biomonitoring rare elements hard to detect by conventional means
- Conservation implications

Conclusions

- **Biomonitoring rare elements hard to detect by conventional means**
- **Conservation implications**
- **Science outreach**

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