ACTA UNIVERSITATIS SZEGEDIENSIS

PARS CLIMATOLOGICA SCIENTIARUM NATURALIUM

CURAT: ILONA BÁRÁNY-KEVEI

ACTA CLIMATOLOGICA

TOMUS XXXII-XXXIII.

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PREFACE

Professor György Koppány

The current issue of the Acta Climatologica is dedicated to Professor György Koppány, the former head of the Department, on the occasion of his retirement.

Professor György Koppány has acted as the editor of this journal for ten years. During this time, Hungarians as well as other, foreign researchers mainly from the Central-European region, had the possibility to publish the results of their scientific research in the field of Climatology and Meteorology. As the new editor-in-chief of this scientific journal, I would like to continue this editorial tradition, and also to broaden the viewpoint of the Acta Climatologica.

As the present head of the Department together with my collegues, I hope that we can take his professional advice on the further research activities of the Department and he will take active part in the editorial process of the future issues of this scientific journal.

3 September, 1999

Ilona Bárány-Kevei
editor-in-chief

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BIBLIOGRAPHY OF GYÖRGY KOPPÁNY

Books, booklets, lecture notes (könyvek, önálló kiadványok, egyetemi jegyzetek):

1. *Koppány, Gy.*, 1972: *Medium-range forecasting of rainfall and temperature in Hungary. OMSz Kisebb Kiadványai 39*, 56 pp.
2. *Koppány, Gy.*, 1977: *A meteorológiai előrejelzések verifikációjának módszerei. (Methods for verification of meteorological predictions.) Meteorológiai Tanulmányok 5*, OMSZ, 46 pp.
3. *Koppány, Gy.*, 1977: *Az időjárás hosszútávú előrejelzésének alapjai. (Principles of long-range weather-forecasting.) Meteorológiai Tanulmányok 13*, OMSZ, 161 pp.
4. *Koppány, Gy.*, 1977: *Meteorológiai alaptematika. (Elementary knowledge of meteorology.)* TIT Központi Kiadványa, Budapest.
5. *Koppány, Gy.*, 1977: *Az időjáráskutatás korszerű útjai. (Up to date investigations in meteorology.)* TIT Központi Kiadványa, Budapest.
6. *Koppány, Gy.*, 1978: *A légkörkutatás fejlődése 1960 óta. (Development in research of atmosphere science 1960.) TIT Központi Kiadványa*, Budapest.
7. *Koppány, Gy.*, 1978: *Távprognosztika II. (Long-range weather-forecasting 2* - Lecture notes) ELTE TTK, Tankönyvkiadó, Budapest, 174 pp.
8. *Koppány, Gy.*, 1978: *Felhők*, I. kiadás. (*Clouds*, First edition.) Móra Könyvkiadó, Budapest.
9. *Koppány, Gy.*, 1980: *Meteorológus Baráti Körök Munkafüzete. (Guide book for amateur meteorologists.)* TIT Központi Kiadványa, Budapest.
10. *Koppány, Gy.*, 1981: *Az általános légkörzés laboratóriumi modellezése. (Modelling of general atmospheric circulation by laboratory experiments.) Meteorológiai Tanulmányok 37*, OMSZ, 40 pp.
11. *Koppány, Gy.*, 1983: *Felhők*, II. kiadás. (*Clouds*, Second edition.) Móra Könyvkiadó, Budapest.
12. *Koppány, Gy.*, 1984: *Az időjárás hosszútávú előrejelzése. (Longe-range forecasting of weather.)* Gyorsuló idő sorozat, Magvető Kiadó, Budapest, 127 pp.
13. *Koppány, Gy.*, 1986: *Az időjárás hosszabbtartamú előrejelzése. (Longe-range weather-forecasting.* - Lecture notes) ELTE TTK. Tankönyvkiadó, Budapest. 150 o.
14. *Koppány, Gy.*, 1989: *Légköri erőforrások. (Atmospheric energy resources.* - Lecture notes) JATE TTK, JATE Kiadó, Szeged, 104 pp.
15. *Koppány, Gy.*, 1993: *Lakható marad-e a Föld? A légkör és élővilág. (Remains the Earth inhabitable? Atmosphere and biosphere.)* Akadémiai Kiadó, Budapest, 120 pp.
16. *Koppány, Gy.*, 1996: *Bevezetés a paleoklimatológiába. (Introduction to paleoclimatology.* - Lecture notes) JATEPress, Szeged. 60 pp.

17. *Koppány, Gy.*, 1997: *Bácskai életképek. Emlékek Bajmokról. (Every-day life in Bácska. Memories from Bajmok.)* Private issue, ISBN 963 550 153 6, Szeged, 84 pp.

Parts of books (könyvrészletek):

1. Szerk. (ed.) *Götz, G.*, 1966: *Sturmwarnung am Balatonsee.* OMI Kiadvány, Budapest. 45-47.
2. Szerk. (ed.) *Ambrózy, P.*, 1967: *Az időjárás dinamikus előrejelzésének alapjai. (Principles of dynamical weather forecasting.) OMI Hivatalos Kiadványai 31*, Budapest, pp. 186-207.
3. *Koppány, Gy., Rábai, A. and Szalma, J.*, 1977: *Prognózis Értelmező Szótár. (Explanatory dictionary of weather prediction.) Meteorológiai Tanulmányok 22*, Budapest, 30 pp.
4. *Koppány, Gy. and Sallai, M.*, 1984: A 30 napos hőmérsékleti és a 10 napos csapadék előrejelzések verifikációja. (Verification of 30 day temperature and 10 day precipitation forecasts, respectively.) *Meteorológiai Tanulmányok 52*, OMSZ, 20 pp.
5. Szerk. (eds.) *Czelnai, R. and Szepesi, Dezsőné*, 1986: *Műszaki Értelmező Szótár. Meteorológia. - 150 címszó (Technical explanatory dictionary. Meteorology. - 150 entries)* Akadémiai Kiadó, Budapest.
6. *Koppány, Gy.*, 1991: *Remembering Walt Roberts.* University Corporation for Atmospheric Research, Boulder, Colorado. p 100.
7. Szerk. (ed.) *Koppány, Gy.*, 1995: *Matematikai segédanyag földrajz szakos egyetemi és főiskolai hallgatók részére. (Subsidiary lecture notes of mathematics for students of geography.)* JATEPress, Szeged, 3-9.
8. Szerk. (eds.) *Simon, A. and Tänczer, T.*: *Fejezetek a magyar meteorológia történetéből 1971-1995. A meteorológia oktatása: József Attila Tudományegyetem. (Details of the history of meteorology in Hungary 1971-1995. Education of meteorology: J. A. University of Szeged.)* OMSZ, Budapest, 422-424.
9. *Koppány, Gy.*, 1999: *Climate changes and their influence on the course of human history.* In *Encyclopedia of life support systems.* Chapter 1.4.1.1. EOLSS Publishers Co. Ltd., (in press).

Native and foreign publications (hazai és külföldi szakcikkek):

1. *Koppány, Gy.*, 1957: Anticiklon gyakoriság az Északi-félgömbön. (Frequency distribution of anticyclones in Northern Hemisphere.) *Időjárás 61*, 41-45.
2. *Koppány, Gy.*, 1957: Az 1957-es nyár rendkívüli melegperiódusának makroszinoptikai vizsgálata. (Macrosynoptic investigation of extreme warm period in 1957 summer.) *Időjárás 61*, 284-289.
3. *Koppány, Gy.*, 1958: A sarki léghalmazok felépülése és kapcsolatuk az általános légkörzéssel. (Development of arctic high pressure centres and their link with general circulation.) *Beszámolókötet 1958*, 54-62.

4. *Koppány, Gy.*, 1958: A futóáramok tanulmányozásának legújabb eredményeiről. (Most recent results of investigations of jet streams.) *Időjárás 62*, 115-116.
5. *Koppány, Gy.*, 1959: A lehűlésgócok mozgása az atlanti-európai térségben. (Motion of cold air masses in Atlantic-European region.) *Időjárás 63*, 108-110.
6. *Koppány, Gy.*, 1959: Alaszka térségéből kiinduló hidegfrontok hatása Közép-Európa időjárására. (Cold fronts starting from Alaska and their effect on weather in Central-Europe.) *Időjárás 63*, 307.
7. *Koppány, Gy.*, 1959: Példa blocking-helyzet kialakulására az atlanti-európai térségben. (Case study of blocking formation in Atlantic-European region). *Időjárás 63*, 280-285.
8. *Koppány, Gy.*, 1960: Erősen fejlett anticiklonmagok elterjedése az Északi-félgömbön. (Strongly developed anticyclone distribution in Northern Hemisphere.) *Időjárás 64*, 103-105.
9. *Koppány, Gy.*, 1960: A nyugat-európai lezáró anticiklonok felépítéséről a különböző évszakokban. (Formation of blocking anticyclones in Western Europe in different seasons.) *Beszámolókötet 1960*, 94-98.
10. *Koppány, Gy.*, 1961: Az általános légkörzés és a naptevékenység közötti kapcsolat kutatásának legújabb eredményei. (Most recent results of investigations on relationship between the solar activity and the general circulation.) *Időjárás 65*, 298-301.
11. *Koppány, Gy.*, 1961: Néhány tapasztalati szabály a távprognózisok összeállításánál. (Some empirical rules for preparing longe-range forecasts.) *Beszámolókötet 1961*, 49-54.
12. *Koppány, Gy.*, 1962: A hőmérséklet ultratávú előrejelzéséről. (On ultralong-range forecast of temperature.) *Időjárás 66*, 284-285.
13. *Koppány, Gy.*, 1963: A grönlandi hatásközpont légnyomásingadozása és kapcsolata a budapesti hőmérséklettel. (Pressure variations in Greenland and their links with temperature of Budapest.) *Időjárás 67*, 107-110.
14. *Koppány, Gy.*, 1963: A légnyomás 24 órán belüli erős változásának gyakorisága a Sziklás-hg. és Nyugat-Szibéria közötti területen. (Frequency distribution of strong 24 hour pressure changes between Rocky Mountains and Western Siberia.) *Időjárás 67*, 14-20.
15. *Koppány, Gy.*, 1963: Makroszinoptikai módszer a csapadék középtartamú előrejelzésére. (Macrosynoptic method for medium-range forecasting of precipitation.) *Időjárás 67*, 159-162.
16. *Koppány, Gy.*, 1963: Távprognosztikai szabályok statisztikai ellenőrzése. (Statistical test of empirical rules in longe range forecasting.) *Beszámolókötet 1963*, 171-178.
17. *Koppány, Gy.*, 1964: A hőmérséklet 6-8 napra szóló előrejelzése a délkörök mentén mért hőmérsékleti különbségek alapján. (6 to 8 day temperature forecast by means of meridional temperature differences.) *Időjárás 68*, 98-103.
18. *Koppány, Gy.*, 1965: Módszer a hőmérséklet középtávú előrejelzésére. (Method for medium-range forecast of temperature.) *Beszámolókötet 1965*, 125-135.
19. *Koppány, Gy. and Kálmánné*, 1965: Módszer a csapadék középtávú előrejelzésére a téli félévben. (Method for medium-range forecast of temperature in cold seasons.) *Beszámolókötet 1965.*, 136-142.

20. *Koppány, Gy.*, 1965: A légköri energiaciklus öszetevőinek nagyságrendje. (Order of magnitude of components of atmospheric energy cycle.) *Időjárás 69*, 100-104.
21. *Koppány, Gy. and Kálmánné*, 1965: A csapadék középtávú előrejelzése és a 700 mb-os felület cirkulációja. (Medium-range forecast of precipitation and the circulation at 700 mb level.) *Időjárás 69*, 154-159.
22. *Koppány, Gy.*, 1965: A hőmérséklet középtávú előrejelzésének néhány kérdése. (Some questions on medium-range temperature forecast.) *Időjárás 69*, 293-296.
23. *Koppány, Gy. and Kálmánné*, 1966: A hőmérséklet havi anomáliájának előrejelzése. (Prediction of monthly temperature anomalies.) *Időjárás 70*, 230-234.
24. *Koppány, Gy.*, 1967: Közép- és hosszútávú előrejelzések a Szovjetunióban és az Egyesült Államokban. (Medium- and long-range forecasts in the Sowiet Union and in the U.S.A.) *Időjárás 71*, 163-166.
25. *Koppány, Gy.*, 1968: An improved method for the medium-range forecast of precipitation. *Időjárás 72*, 15-24.
26. *Koppány, Gy. and Kapovitsné*, 1968: Test of the medium-range precipitation forecasting method for independent data. *Időjárás 72*, 91-94.
27. *Koppány, Gy.*, 1968: Vozmozhnosti prognoza osadkov i temperatury s maloj zablagovremennostu v Vengrii. Problemi obschej cirkuljacii atmoszferi. *Trudi 3-j vszeszojuznoj konferencii po obschej cirkuljacii atmoszferi, Tbiliszi*, 125-128.
28. *Koppány, Gy.*, 1969: Infravörös sugárzásmérések meteorológiai műholdakkal. (Observations of infrared radiations with satellites.) *Időjárás 73*, 44-48.
29. *Koppány, Gy. and Kapovitsné*, 1969: A középtávú előrejelzések beválásáról. (On reliability of medium-range weather forecasts.) *Időjárás 73*, 214-222.
30. *Koppány, Gy.*, 1969: Infravörös sugárzásmérések meteorológiai műholdakkal. (Measurements of infrared radiation with meteorological satellites.) *Fizikai Szemle 19*, 279-282.
31. *Koppány, Gy. and Kapovitsné*, 1969: A népgazdaság távprognosztikai igényei. (Demands of national economy to long-range weather forecasts.) *Időjárás 73*, 367-368.
32. *Koppány, Gy.*, 1970: A közép-és hosszabbtávú előrejelzések beválásáról. (On reliability of medium- and long-range weather forecasts.) *Beszámolókötet 1970*, 24-28.
33. *Koppány, Gy., Adámy, L. and Kapovitsné*, 1972: Razlozhenie meteorologicheskih polej po estestvennym ortogonalnym sostavlajushchim i vozmozhnosti prilezhenija predljagaenovo metoda pri sostavlenii dolgosrochnih prognozov. *Meteorolgia i Gidrologia*, No.1. 91-97.
34. *Koppány, Gy.*, 1972: Nyomás- és hőmérsékletmezők felbontása természetes ortogonális összetevőkre. (Decomposition of surface pressure and temperature fields into natural ortogonal components.) *Időjárás 76*, 133-145.
35. *Koppány, Gy. and Kaba, M.*, 1972: A Föld-légkör rendszer sugárzás háztartási komponenseinek meghatározása a Meteor-1 műhold méréseiből. (Estimation of components of radiation budget in Earth-atmosphere system by means of satellite observations.) *Beszámolókötet 1972*, 136-142.

36. *Koppány, Gy.*, 1973: Megjegyzés Császár Margit "Az általános cirkuláció egyensúly követelményeiről" c. tanulmányához. (Remarks on publication M. Császár: 'Demands of balance in general circulation.') *Időjárás 77*, 117-119.
37. *Koppány, Gy.*, 1974: Az analógiák extrapolációjának felhasználása a havi és évszakos előrejelzésének készítéséhez. (Use of analogy extrapolations in preparing monthly and seasonal meteorological forecasting.) *Időjárás 78*, 97-108.
38. *Koppány, Gy.*, 1974: Bemerkungen zum Artikel von Martin Teich "Statistische Untersuchung zur Vorhersagbarkeit monatlicher Temperaturanomalien". *Időjárás 78*, 303-304.
39. *Koppány, Gy.*, 1975: Az analógiák hosszútávú extrapolációja. (Long-range extrapolation of analogies.) *Időjárás 79*, 17-27.
40. *Koppány, Gy.*, 1975: Estimation of the life span of atmospheric motion systems by means of atmospheric energetics. *Meteorological Magazine 104*, 302-306.
41. *Koppány, Gy.*, 1977: Módszer a természetes időjárási ciklusok tartamának előrejelzésére. (Method for prediction of duration of natural weather periods.) *Időjárás 81*, 216-222.
42. *Koppány, Gy.*, 1978: A meteorológiai információk mennyisége és hasznosításuk néhány kérdése. (Some questions on amounts and utilizations of meteorological informations.) *Meteorológiai Tudományos Napok, 1978. Nov., OMSZ Hiv. Kiadványai 48*, 17-23.
43. *Koppány, Gy. and Hunkár, M.*, 1979:Meteorológiai adatsorok varianciája. (Variance of meteorological data sets.) *Időjárás 83*, 121-127.
44. *Koppány, Gy., Hunkár M. and Rimek, I.*, 1980: Tíz napra szóló csapadék előrejelzési módszer. (Method for ten day forecast of precipitation.) *Beszámolókötet 1980*, 70-80.
45. *Koppány, Gy.*, 1980: A Föld és a bolygók általános légkörzésének laboratóriumi modellje. (Laboratory model for presentation of general atmospheric circulation of Earth and planets.) *Földfelszíni és meteorológiai megfigyelések a világűrből, KASZ, MTESZ ankét, Vác-Penc*, 227-237.
46. *Koppány, Gy.*, 1981: Some aspects of the predictability of weather. *Proceedings of the Symposium on Current Problems of Weatherprediction, Vienna*, 56-59.
47. *Koppány, Gy.*, 1981: Az éghajlatingadozások kutatásának eszközei, együttműködés különböző tudományágakkal. (Means in research of climate changes; co-operations among different disciplines.) *MTA X. Osztályának Közleményei 14, No. 2-4*, 193-207.
48. *Koppány, Gy.*, 1982: Tíznapos csapadék-előrejelzési módszer a magyarországi vízgyűjtő területekre. (Method of ten day precipitation forecasting for different catchments in Hungary. *Vízügyi Közlemények 64*, 220-232.
49. *Koppány, Gy., Kmetyko K., Maller, A. and Vissy, K.*, 1983: A meteorológiai előrejelzések felhasználásával elérhető energiatakarékosság lehetőségei az energiatermeléshez és fogyasztáshoz kapcsolódó népgazdasági ágazatokban. (Attainable economy in energy consumption making use of meteorological predictions.) *Energiagazdálkodás 24*, 322-324.
50. *Koppány, Gy.*, 1983: Légköri energiaforrások. (Atmospheric resources of energy.) *Műszaki élet 38, No. 16*, 11.

51. *Koppány, Gy.*, 1983: Az időjárás 30 napos előrejelzése analógia-kereső eljárással. (30 day weather forecast by means of analogies.) *Időjárás 87*, 274-280.
52. *Koppány, Gy., Kmetyko, K., Maller, A. and Vissy, K.*, 1984: A meteorológiai előrejelzések felhasználásával elérhető takarékosság a népgazdaság különböző ágazataiban. (Attainable economy by means of meteorological forecasts.) *Meteorológiai Tudományos Napok 82, OMSZ Hiv. Kiadványai 57*, 19-25.
53. *Koppány, Gy.*, 1985: Required and attainable information in weather prediction. *Proceedings of the Symposium on Current Problems of Medium and Long Range Weather Forecasts, Budapest, April 15-19, 1985*, 9-11.
54. *Koppány, Gy.*, 1985: Conclusions from the investigation of the energetics of atmospheric motion systems. *Proceedings of the Symposium... see above, Budapest, April 15-19, 1985*, 130-136.
55. *Koppány, Gy. and Kiss, Á.*, 1985: A hőmérséklet és a szélirány változékonysága Szegeden a Péczely-féle makroszinoptikus helyzetekben. (Variabilities of the temperature and wind directions in Szeged in various Péczely's macrosynoptic situations.) *Időjárás 89*, 269-277.
56. *Koppány, Gy.*, 1985: Climatic research and weather-forecast. *Acta Climatologica Szegediensis 18-20*, 25-29.
57. *Koppány, Gy., Maller, A. and Rimek, I.*, 1986: 30-day forecasts and their economic value. *Proceedings of First WMO Conference on Long-Range Forecasting, Sofia, 29 Sept. - 3 Oct., 1986*, WMO, Geneva., 64.
58. *Koppány, Gy.*, 1986: Néhány megjegyzés az időjárás és éghajlat fogalmáról. (Some notes on concepts of weather and climate.) *Időjárás 90*, 295-299.
59. *Koppány, Gy. and Kiss, Á.*, 1987: A hőmérséklet és a szélirány változékonysága Szegeden a Péczely-féle makroszinoptikus helyzetekben az átmeneti évszakokban. (Variabilities of the temperature and the wind directions in Szeged in spring and in autumn in various Péczely's patterns.) *Időjárás 91*, 23-33.
60. *Koppány, Gy.*, 1987: Climatic fluctuations in the 200 year temperature series of Budapest. *A Csehszlovák és Magyar Meteorológiai Társaság közös (10.) Vándorgyűlésének Kiadványa, Brno, 1987. aug. 25-27.*, 131-139.
61. *Koppány, Gy. and Hegedűs, T.*, 1987: A csapadék eloszlása a hét napjai szerint. (Mean amounts of precipitation in various days of the week.) *Légkör 32, No. 4*, 25-27.
62. *Koppány, Gy.*, 1988: A februári időjárás és a márciusi hőmérséklet kapcsolata. (Link between February weather and March temperature.) *Légkör 33, No. 2*, 7-9.
63. *Koppány, Gy.*, 1989: Climatic fluctuations in the 200 year temperature series in Europe. *Proceedings of International Symposium, Climatic Change in the Historical and Instrumental Periods, Brno, 12-16 June, 1989*, 211-214.
64. *Koppány, Gy.*, 1989: An approach from information theory to weather forecasts. *Proceedings of Hungarian-Czechoslovak Meteorological Conference, Gödöllő, 21-24 August, 1989*, 57-63.
65. *Koppány, Gy.*, 1989: A sztratoszféra cirkulációjának tavaszi átfordulása az északi

hemiszférán. (Spring turnover of the stratospheric circulation in the Northern Hemisphere.) *Időjárás 93*, 340-350.

66. *Koppány, Gy.*, 1989: A fűtési idény és az éghajlat. (Heating season and the climate.) *Légkör 34, No. 4*, 15-17.
67. *Koppány, Gy.*, 1989: The variability of the temperature and wind direction at Szeged in various large scale pattern. *Acta Climatologica Szegediensis 21-23*, 3-22.
68. *Koppány, Gy.*, 1989: Isochrones of the wettest months in continental areas. *Acta Climatologica Szegediensis 21-23*, 33-50.
69. *Koppány, Gy. and Pelle, L.*, 1990: A nagycsapadékból származó víztömeg becsült potenciális energiája középhegységeinkben. Esettanulmányok. (Estimated potential energy of water mass arising from heavy rains in highlands of Hungary. Case studies.) *Időjárás, 94*, 168-175.
70. *Koppány, Gy.*, 1990: A meridionális szélkomponens ingadozása az alsó sztratoszférában. (Variation of the meridional wind in lower stratosphere.) *Időjárás 95*, 94-100.
71. *Koppány, Gy.*, 1990: A váratlan időjárás-változások energetikai háttere. (Energetic background of unexpected changes in the atmosphere.) *Acta Geographica Debrecina 28-29*, 61-74.
72. *Koppány, Gy.*, 1992: Gaia Hypothesis. In Lukács B. et al. (eds): *Mutual Dynamics of Organisational Levels in Evolution. KFKI, Budapest, 1992-32/c.* 29-33.
73. *Koppány, Gy.*, 1992: Temperature variations in Europe and North America since the beginning of instrumental obeservation. *Acta Climatologica Szegediensis 24-26*, 23-32.
74. *Koppány, Gy. and Unger, J.*, 1992: Mediterranean climatic character in the annual march of precipitation. *Acta Climatologica Szegediensis 24-26*, 59-71.
75. *Koppány, Gy.*, 1993: Ózonritkulás az Antarktisz felett. (Ozon depletion over Antarctica.) *A földrajz tanítása I, No. 1*, 7-9.
76. *Koppány, Gy.*, 1993: Az éghajlat fogalmáról. (On concept of the climate.) *Légkör 38, Különszám*, 18-19.
77. *Koppány, Gy.*, 1993: Nemzetközi egyezmények a légkör és az éghajlat védelmére. (International agreements on protection of the atmosphere and the climate.) *A földrajz tanítása I, No. 3*, 19-21.
78. *Koppány, Gy.*, 1993: Various types of changes in climatic series of Budapest and Szeged. Comparison with remote climatic stations. *Acta Climatologica Szegediensis 27*, 17-26.
79. *Koppány, Gy. and Unger, J.*, 1993: The tendencies of the mediterranean climatic character in Hungary. *Acta Climatologica Szegediensis 27*, 27-32.
80. *Koppány, Gy.*, 1994: Az éghajlat fogalmáról. (On concept of the climate) *Légkör 39, Különszám*, 33-36.
81. *Koppány, Gy.*, 1994: Válasz Szunyogh István bírálatára. (Response on criticizm of I. Szunyogh.) *Légkör 39, No. 1*, 31-32.
82. *Koppány, Gy. and Csikász, L.*, 1994: An attempt to on prediction of drought in Hungary. *Proceedings of Contemporary Climatology Conference* (*Eds. R. Brazdil and M. Kolár*),

Brno, 1994, 320-327.
83. *Koppány, Gy.*, 1994: Bölcselkedés az időjárásról, éghajlatról. (Philosophizing on weather and climate.) *Légkör 39, No 3*, 12-15.
84. *Koppány, Gy.*, 1994: Temperature variation in Europe and North America since the beginning of insztrumental observations. *Időjárás 98, 227-236.*
85. *Koppány, Gy.*, 1995: Az éghajlat fogalmáról. (On concept of the climate.) *A földrajz tanítása 3, No. 2*, 12-18.
86. *Koppány, Gy., Unger, J. and Csikász, L.*, 1995: Teleconnection method for drought-prediction in five regions of Great Hungarian Plain. *Climatology and Air Pollution Conference. Universidad nacional de Cuyo Facultad de Filosofia y Letras, Mendoza, Argentina, 1995. Aug. 13-20*, 387-396.
87. *Koppány, Gy.*, 1995: Microclimate investigations in and near the forest of Ásotthalom. *Acta Climatologica Szegediensis 28-29*, 47-52.
88. *Koppány, Gy. and Makra, L.*, 1995: Persistence probability of the drought index made by Pálfai for five regions of the Hungarian Plain. *Acta Climatologica Szegediensis 28-29*, 53-61.
89. *Koppány, Gy.*, 1996: Visszafordíthatatlan környezetrombolás? (Irreversible devastation of the environment?) *Természet világa 127, No. 2*, 62-62.
90. *Koppány, Gy.*, 1996: Mutual evolution of terrestrial atmosphere and biosphere. *Acta Climatologica Szegediensis 30*, 31-40.
91. *Koppány, Gy. and Kiss, A.*, 1996: Mean daily rain depending on wind direction. *Acta Climatologica Szegediensis 30*, 71-79.
92. *Koppány, Gy. and Nagwa, A.A.K.*, 1996: Strong wind occurances in Egypt in 1994. *Acta Climatologica Szegediensis 30*, 81-88.
93. *Koppány, Gy., Makra, L., Unger, J. and Csikász, L.*, 1996: Aszályelőrejelzési eljárások kidolgozása és verifikálása az Alföld öt körzetére. (Elaboration and verification of methods for drought predictions in five regions of Hungarian Plain.) *The 2nd Symposium on Environmental Problems, Szeged, Nov. 6. 1996*, 3-37.
94. *Koppány, Gy.*, 1996: International Conference on Climatology and Air Pollution, Mendoza, Argentina, August 14-21. *Időjárás, 100*, 274-275.
95. *Koppány, Gy.*, 1997: Az aszályosság előrejelzésének módszerei és alkalmazásuk a Dél-Alföldön. (Methods of drought prediction and their application on South Part of Hungarian Plain.) *A geokörnyezet szerepe a területfejlesztéstől a területrendezésig Konferencia, Szeged, 1997. Sept. 25-26*, (in press).
96. *Koppány, Gy.*, 1997: A nagy földi szélrendszerek: a passzátok és monszunok. (The great terrestrial wind systems: trade winds and monsoons.) *A földrajz tanítása 5, No. 3-4.* 16-19.
97. *Koppány, Gy.*, 1997: A szén körforgása a Föld-légkör rendszerben és az éghajlat változása. (The carbon cycle in the Earth-atmosphere system and the climate change.) *Meteorológiai Tudományos Napok, OMSZ*, 209-211.
98. *Koppány, Gy.*, 1997: The carbon cycle in the Earth-atmosphere system and the climate

change. *Acta Climatologica Szegediensis 31*, 7-15.
99. *Koppány, Gy.*, 1998: Időjárás és történelem. (Weather and history.) *Természet világa 129, Különszám*, 10-12.

Public educational articles (ismeretterjesztő cikkek):

1. *Koppány, Gy.*, 1960: Érdekes fényjelenség altocumulus lenticularis felhőn. *Légkör 5, No. 4*, 9-11.
2. *Koppány, Gy.*, 1961: Az 1961. február 15-i napfogyatkozás meteorológiai hatása. *Élet és Tudomány 16, No. 15.*
3. *Koppány, Gy.*, 1961: Mekkora ereje volt a chilei szökőárnak? *Élet és Tudomány 16, No. 30*, 953-954.
4. *Koppány, Gy.*, 1961: Az 1961. II. 15-i napfogyatkozás meteorológiai vonatkozásai Budapesten. *Légkör 6, No. 2*, 22-25.
5. *Koppány, Gy.*, 1962: Kisebb méretű tromba a dunaújvárosi vasútvonal mentén. *Légkör 6, No. 3*, 23.
6. *Koppány, Gy.*, 1962: Tudjuk-e milyen lesz az 1962-es év időjárása? *Élet és Tudomány 1962. évi kalendáriuma*, 405-407.
7. *Koppány, Gy.*, 1963: A téli hónapok jellemző felhőfajtái. *Légkör 8, No. 3*, 62-64.
8. *Koppány, Gy.*, 1963: A magasszintű felhőfajták. *Légkör 8, No. 4*, 94.
9. *Koppány, Gy.*, 1964: Milyen hatása van a naptevékenységnek az időjárásra? *Élet és Tudomány 19, No. 36.*
10. *Koppány, Gy.*, 1964: A nyári égbolt jellegzetes felhőfajtái. *Légkör 9, No. 1*, 5-8.
11. *Koppány, Gy.*, 1965: Az első magyar tudós (dr. Titkos Ervin) az Antarktiszon. *Élet és Tudomány 1965. évi kalandáriuma.*
12. *Koppány, Gy.*, 1965: A "bécsi időjárási naptár" a meteorológia szemével. *Légkör 10, No. 4*, 102-106.
13. *Koppány, Gy.*, 1965: A bécsi időjárás előrejelzés a tények tükrében. *Élet és Tudomány 20, No. 45*, 2132-2135.
14. *Koppány, Gy.*, 1967: A tudománytalan bécsi időjárási naptár tévedései az utóbbi években. *Légkör 12, No. 2*, 34-36.
15. *Koppány, Gy.*, 1967: Hogyan készülnek a távelőrejelzések a Szovjetunióban és az Egyesült Államokban? *Légkör 12, No. 2*, 39-41.
16. *Koppány, Gy.*, 1967: Várható időjárás - hosszabb időre. *Élet és Tudomány 22, No. 48*, 2291-2294.
17. *Koppány, Gy.*, 1969: Meteorológia és technika. *Műszaki Élet 24, No. 16*, 1.
18. *Koppány, Gy.*, 1969: Miért válik be vagy miért nem válik be a prognózis? *Légkör 14, No. 3*, 52-54.
19. *Koppány, Gy.*, 1970: Honnan tudjuk milyen lesz az időjárás? *Élet és Tudomány 25, No. 4.*
20. *Koppány, Gy.*, 1970: 100 éves az Egyesült Államok Meteorológiai Szolgálata. *Légkör 15, No. 3*, 60-62.

21. *Koppány, Gy.*, 1971: A műholdak és a Föld külső légköre. *Légkör 16, No. 1*, 9-11.
22. *Koppány, Gy.*, 1971: Éghajlatváltozás vagy éghajlatingadozás. *Természet Világa 102, No. 11*, 498-500.
23. *Koppány, Gy.*, 1973: Milyen lesz ez a nyár? *Magyarország 10, No. 21*, 21.
24. *Koppány, Gy.*, 1973: Lehet-e egy évre előrejelezni az időjárást? *Kincses Kalendárium 1973*, 26-29.
25. *Koppány, Gy.*, 1974: Megváltozott-e az éghajlatunk? *Központi Sajtószolgálat, 1974 május.*
26. *Koppány, Gy.*, 1974: Mikor menjünk az idén nyaralni? *Központi Sajtószolgálat, 1974 június.*
27. *Koppány, Gy.*, 1974: Hosszú, forró nyár? Meteorológusok az időjárási előrejelzések lehetőségeiről. *Ország-Világ 18, No. 34*, 12-13.
28. *Koppány, Gy.*, 1974: A bécsi és a belgrádi időjós naptárakról. *Központi Sajtószolgálat.*
29. *Koppány, Gy.*, 1974: Ismétlik-e önmagukat az időjárási események? *Természet Világa 105, No. 11*, 510-514.
30. *Koppány, Gy.*, 1974: Elfelejti-e az időjárás a múltat? *Légkör 19, No. 4*, 94-99.
31. *Koppány, Gy.*, 1975: Meddig emlékezhet az időjárás a múltra? *Légkör 20, No. 1*, 4-8.
32. *Koppány, Gy.*, 1975: Hosszútávú időjárás.előrejelzés világméretű összefogással. *Természet Világa 106, No. 5*, 230-236.
33. *Koppány, Gy.*, 1975: Földméretű meteorológiai adatgyűjtés. *Élet és Tudomány 30, No. 40*, 1900-1904.
34. *Koppány, Gy.*, 1975: A meteorológiai előrejelzés akadályai. *Élet és Tudomány 30, No. 42*, 1977-1981.
35. *Koppány, Gy.*, 1976: A naptevékenység és az időjárás. *Természet Világa 107, No. 6*, 269-272.
36. *Koppány, Gy.*, 1977: A Föld vízháztartása és a meteorológia. *Légkör 22, No. 1*, 5-11.
37. *Koppány, Gy.*, 1977: A százéves kalendáriumtól a modelles kísérletekig. *Élet és Tudomány 32, No. 37*, 1159-1161.
38. *Koppány, Gy.*, 1977: Meddig "emlékezik" az időjárás a múltra? *Élet és Tudomány 32, No. 38*, 1203-1205.
39. *Koppány, Gy.*, 1979: A felhők sajátságos világa. *Természet Világa 110, No. 6*, 276-277.
40. *Koppány, Gy.*, 1979: Gyilkos tornádók az Egyesült Államok déli részén. *Élet és Tudomány 34, No. 26*, 811.
41. *Koppány, Gy.*, 1979: Földünk éghajlatváltozásai. *Élet és Tudomány 43, No. 38*, 1192-1195.
42. *Koppány, Gy.*, 1979: Meteorológia világméretekben. *Népszava 1979. márc. 4.*, 6.
43. *Koppány, Gy.*, 1980: Az éghajlatváltozások modellezése. *Élet és Tudomány 35, No. 8*, 166-169.
44. *Koppány, Gy.*, 1980: "Éghajlat és történelem" konferencia a kelet-angliai Norwichban. *Légkör 25, No. 1*, 30-32.
45. *Koppány, Gy.*, 1980: Mennyire és miért rendkívüli az időjárás? *Ország-Világ 24, No. 26*, 12-13.
46. *Koppány, Gy.*, 1981: Időjárás-előrejelzés egy hónapra. *Élet és Tudomány 36, No. 14*, 421-423.

47. *Koppány, Gy.*, 1981: 100 éve történt. *Légkör 26, No. 1.*,32.
48. *Koppány, Gy.*, 1981: 100 éve történt. *Légkör 26, No. 3.*, 33.
49. *Koppány, Gy.*, 1981: 100 éve történt. *Légkör 26, No. 4.*, 28.
50. *Koppány, Gy.*, 1981: A Föld vízkészletei és a meteorológia. *Föld és Ég 16, No. 6*, 184-188.
51. *Koppány, Gy. és Kmetykó, K.*, 1981: A meteorológiai előrejelzések népgazdasági hasznosítása Magyarországon. *Légkör 26, No. 3*, 2-5.
52. *Koppány, Gy.*, 1982: 100 éve történt. *Légkör 27, No. 1.*, 31.
53. *Koppány, Gy.*, 1982: 100 éve történt. *Légkör 27, No. 3.*, 27
54. *Koppány, Gy. és Titkos E.*, 1983: Szélsőséges enyhe január és lehetséges okai. *Magyarország 20, No. 13*, 78-79.
55. *Koppány, Gy.*, 1984: Helyzetkép a hóviszonyokról. *Símagazin 1984*, 48-49.
56. *Koppány, Gy.*, 1984: Milyen pontosak lehetnek egyáltalán a meteorológiai előrejelzések. *Népszabadság 1984. szept. 25.*, 10..
57. *Koppány, Gy.*, 1984: Megváltozott-e teleink éghajlata? *Népszabadság 1984. dec. 15.*, 10.
58. *Koppány, Gy.*, 1985: Az időjárás "forgatókönyve". *Élet és Tudomány 40, No. 31*, 968-970.
59. *Koppány, Gy.*, 1985: Beválnak-e a hosszútávú időjárás-előrejelzések? *Népszabadság 1985. ápr. 9.*, 10.
60. *Koppány, Gy.*, 1985: Rendkívüli volt-e az idei tél? *Magyar Nemzet 1985. ápr. 12.*, 9.
61. *Koppány, Gy.*, 1985: Elolvad-e az Antarktisz jégtakarója? *Népszabadság, 1985. júl. 23.*, 10.
62. *Koppány, Gy.*, 1986: Az átlagos időjárás. *Az RTV Újság Kalendáriuma 1986*, 4-27.
63. *Koppány, Gy.*, 1986: Az afrikai aszály, meteorológus szemmel. *Népszabadság, 1986. febr. 22.*, 11.
64. *Koppány, Gy.*, 1986: Éghajlatingadozások a téli hőmérséklet alakulásában Budapesten. *Légkör 31, No. 1*, 22-24.
65. *Koppány, Gy.*, 1986: Éghajlatingadozások a tavasztól őszig terjedő időszak hőmérsékletének alakulásában Budapesten. *Légkör 31, No. 2*, 6-8.
66. *Koppány, Gy.*, 1987: Elektromos fényjelenségek a légkörben. *Népszabadság, 1987. jún. 16.*, 10.
67. *Koppány, Gy.*, 1987: Gyilkos időjárás? *Délmagyarország 77, 1987. aug. 15.*, 6.
68. *Koppány, Gy.*, 1987: Változik-e az éghajlat? *Élet és Tudomány 42, No. 47*, 1475-1477..
69. *Koppány, Gy.*, 1988: A csapadék és vízienergia. *Népszabadság, 1988. dec. 27.*, 10.
70. *Koppány, Gy.*, 1989: Rendhagyó télelő volt tavaly. *Délmagyarország, 1989. január 19., 4.*
71. *Koppány, Gy.*, 1989: A fűtési idény és az éghajlat. *Légkör 34, No. 4.*, 15-17.
72. *Koppány, Gy.*, 1989: Éghajlati katasztrófa vagy a természet önszabályozása. *Délmagyarország, 1989. február 11.*, 6.
73. *Koppány, Gy.*, 1989: Szeszélyes évszakok. *Népszabadság, 1989. ápr. 10.*, 8.
74. *Koppány, Gy.*, 1989: A tudomány és a fűtési számla. *Délmagyarország, 1989. szept. 29.*, 4.
75. *Koppány, Gy.*, 1990: Várható időjárás Kr.e.100-Kr.u.100 között. *Szemtanú 1, No. 1*, 45.
76. *Koppány, Gy.*, 1990: Várható időjárás 1848-49-ben. *Szemtanú 1, No. 2*, 45.
77. *Koppány, Gy.*, 1990: Várható időjárás 1500-1600 között. *Szemtanú 1, No. 3*, 45.

78. *Koppány, Gy.*, 1990: Várható időjárás 700-1000 között. *Szemtanú 1, No. 4*, 45.
79. *Koppány, Gy.*, 1991: Lesz-e nálunk fekete eső? Égő kuwaiti olajkutak. *Délmagyarország 1991. ápr. 2.*, 3.
80. *Koppány, Gy.*, 1991: Várható időjárás 1789-1847 között. *Szemtanú 2, No. 2*, 45.
81. *Koppány, Gy.*, 1992: Várható időjárás Kr.e.1100-500 között. *Szemtanú 3, No. 4*, 43.
82. *Koppány, Gy.*, 1992: Véget ért egy aszálykorszak. *Délmagyarország 1992. jan. 10.*
83. *Koppány, Gy.*, 1992: Véget ért egy aszálykorszak. *Kék Délvilág 1992. jan. 10.*
84. *Koppány, Gy.*, 1992: Szeszélyes hónapok. *Délmagyarország 1992. jún. 13.*, 4.
85. *Koppány, Gy.*, 1992: Hosszú forró nyár vagy megkésett kánikula. *Kék Délvilág 1992. szept. 15.*
86. *Koppány, Gy.*, 1992: Várható időjárás 1000-1300 között. *Szemtanú 3, No. 1*, 45.
87. *Koppány, Gy.*, 1992: Várható időjárás Kr.e.1800-Kr.e.1100 között. *Szemtanú 3, No. 2*, 45.
88. *Koppány, Gy.*, 1992: Várható időjárás 1300-1500 között. *Szemtanú (Eye Witness, special edition for EXPO '92 Sevilla*, 22.
89. *Koppány, Gy.*, 1992: Várható időjárás 1300-1500 között. *Szemtanú 3, No. 3*, 45.
90. *Koppány, Gy.*, 1993: Várható időjárás 1850-1913 között. *Szemtanú 4, No. 1*, 45.
91. *Koppány, Gy.*, 1993: Várható időjárás 1850-1913 között. *Szemtanú (Ősrobbanástól a közeli jövőig) 4, No. 2*, 9.
92. *Koppány, Gy.*, 1993: Környezetvédelem itthon és a nagyvilágban. *Délmagyarország 1993. febr. 16.*, 7.
93. *Koppány, Gy.*, 1993: 1993 az időjárási szélsőségek éve. *Délmagyarország 1993. jún. 7.*, 8.
94. *Koppány, Gy., Maller, A. és Varga, L.*, 1993: Huszonötéves a magyar operatív középtávú időjárás-előrejelzés. *Légkör 38, No. 4*, 17-20.
95. *Koppány, Gy.*, 1994: Példátlan aszálysorozat Magyarországon. *Délmagyarország 1994. jan. 12.*, 13.
96. *Koppány, Gy.*, 1994: Péczely György emlékezete. *Délmagyarország 1994. márc. 3.*, 6.
97. *Koppány, Gy.*, 1994: 100 milliárdos aszályok. *Új Magyarország 1994. márc. 5.*, 16.
98. *Koppány, Gy.*, 1994: A hőség emberi háttere. *Délmagyarország 1994. szept. 3.*
99. *Koppány, Gy.*, 1995: Az időjárás vagy az ember van változóban? *Szegedi Napló 1, No. 10*, 4.
100. *Koppány, Gy.*, 1995: Az időjárás vagy az ember van változóban? *Délmagyarország 1995. máj. 24.*, 4.
101. *Koppány, Gy.*, 1995: Az éghajlat fogalmáról. *A földrajz tanítása 3, No. 2*, 12-18.
102. *Koppány, Gy.*, 1995: Várható időjárás 100-700 között. *Szemtanú 6, No. 1*, 45.
103. *Koppány, Gy.*, 1996: Ötven éves a magyar űrkutatás. *Délmagyarország 1996. febr. 8.*, 6.
104. *Koppány, Gy.*, 1996: A légköri ózon védelme. *Légkör 41, No. 3*, 7-9.
105. *Koppány, Gy.*, 1996: A Föld-légkör rendszer sebezhetősége. *Légkör 41, No. 4*, 11-13.

Not published studies, lectures (Nem publikált tanulmányok, előadások):

1964: 1. A geosztrófikus széltörvény felhasználása a balatoni szél előrejelzésére. A MMT 1964. évi szakirodalmi pályázatán díjat nyert dolgozat.

1967: 2. A csapadék és a hőmérséklet középtávú előrejelzésének lehetőségei Magyarországon. Kandidátusi disszertáció, 89.o.

1976: 3. Opponensi vélemény. Vita Makainé Császár Margit: "Energia-átalakulások a légkörben" c. kandidátusi értekezésről. Budapest, 1976. május 24.

1979: 4. "Földünk éghajlatváltozásai" c. vándorkiállításnak a TIT Bocskai úti Stúdiójában történt (Budapest, XI. ker.) megnyitásán elhangzott megnyitó előadás 1979. február 5-én.

5. A földi légkörzés laboratóriumi modellje. A 30. Csillagászati Hét alkalmából a TIT Bp-i Planetáriumban elhangzott előadás. Budapest, 1979. október 15.

1983: 6. Az időjárás hosszabbtartamú előrejelezhetősége. Akadémiai doktori értekezés, 77. o.

1984: 7. A meteorológiai ismeretterjesztés fontosabb kérdései. A TIT Fizikai-meteorológiai Választmánya és a Zala-megyei Szervezete által szervezett országos tanácskozáson elhangzott előadás. Nagykanizsa, 1984. június 27-29.

1987: 8. A 30 napos hőmérsékleti előrejelzések verifikációja az 1986. évre. Kutatási beszámoló. Kézirat.

1988: 9. Opponensi vélemény. Vita Ahmed Fouad Hamed: "Idősorok periodicitása..." c. kandidátusi értekezésről. Budapest, 1988. január 14.

1989: 10. A sztratoszféra cirkulációja és az ózon. XVII. Ionoszféra és magnetoszféra szeminárium. Szeged, 1989. október 30-november 1.

1991: 11. Opponensi vélemény. Vita Götz Gusztáv: "A légköri változékonyság teljes spektruma..." c. akadémiai doktori értekezésről. Budapest, 1991. szeptember 23.

1993: 12. Opponensi vélemény. Vita Tóth Géza: " A magyarországi aerológiai kutatás fejlesztése" c. akadémiai doktori értekezéséről. Budapest, 1993. szeptember 23.

13. Lakható marad-e a Föld? A Gaia-elmélet. Szeged Közéleti Kávéház sorozatban elhangzott előadás. Szeged, 1993. november 4.

1995: 14. Természetbölcselet és a világkatasztrófáktól való félelem. KÉSZ Szabad-egyetemen elhangzott előadás. Szeged, 1995. szeptember 27.

15. Ózonlyuk és globális fölmelegedés. Keresztény Pedagóguskamara Szentesi Csoportja meghívására elhangzott előadás. Szentes, 1995. október 12.

1996: 16. A magyar meterológia belapcsolódása az űrkutatásba. Ötven éves a magyar űrkutatás. Bay Zoltán emlékülésen elhangzott előadás. SZAB, Szeged, 1996. szeptember 9.

17. A Föld-légkör rendszer sebezhetősége. A "Természet környezeti állapota' 96" konferencián elhangzott megnyitó előadás. Kecskemét, 1996. szeptember 20.

1997: 18. A szén körforgása a Föld-légkör rendszerben és az éghajlat változása. A légköri szén-dioxid a jövő században c. vitaülésén elhangzott előadás. MTA, Budapest, 1997. november 4.

1998: 19. A Biblia és a természettudományok. A KÉSZ Szabadegyetemen elhangzott előadás. Szeged, 1998. ápr. 22.

Organization of national and international meetings (nemzetközi és hazai tudományos konferenciák illetve rendezvények szervezése):

1979: 1. "Földünk éghajlatváltozásai" c. 24x2 m^2-es állvány tablóból álló vándorkiállítás a TIT Stúdió támogatásával. Megnyitás 1979. február 5. Budapest.

1985: 2. "Current promlems of medium and long range weather forecasts". Budapest, April 15-19, 1985. MTESZ, Technika Háza. Az OMSZ és MMT támogatásával.

1996: 3. "50 éves a magyar űrkutatás" jubileumi ankét Bay Zoltán emlékére. Szeged, SzAB, 1996. szept. 9.

Reading translations, translation (fordítások lektorálása, illetve fordítás):

1981: 1. Szanyin, V.M.: Bolygónk ruhatára. GARP Atlanti-Trópusi Kísérlet. (Oroszból fordította: Jovánovics M., lektorálta: K. Gy.) Kozmosz, Kárpáti Kiadó.

1992: 2. Cosgrove, B.: Időjárás. Szemtanú. (Angolból fordította: Both Előd, lektorálta: K.Gy.) Park Kiadó.

1987: 3. (Kleine Enzyklopädie Natur. VEB Bibliographischer Institute, Leipzig, 1971) Természettudományi kisenciklopédia. 2.3. fejezet: A légkör (atmoszféra), Gondolat, Budapest, 127-165.

Book reviews (könyvismertetések):

1959: 1. Abbot, C.G., : Long-range Weather Forecasting. *Időjárás 63*, 189.

1960: 2. Pogosjan, H.P., 1959: Obschaja cirkulacija atmosfery. Leningrad. *Időjárás 64*, 121.

1961: 3. Girs, A.A., 1960: Osnovy dolgosrochnyh prognozov pogody. Leningrad. *Időjárás 65*, 57-58.

1975: 4. Girs, A.A, 1974: Makrocirkuljacionnij metod dolgosrochnih prognozov. Leningrad. *Időjárás 79*, 245.

1983: 5. Ugrjumov, A.I., 1981: Teplovoj rezsim okeana i dolgosrochnie prognozi pogody. Leningrad. *Időjárás 87*, 179.

1984: 6. Tarakanov, G.F., 1982: Tropical Meteorology. *Időjárás 88*, 248.

1985: 7. Péczely Gy., 1984: A Föld éghajlata. Tankönyvkiadó, Budapest. *Időjárás 89*, 114.

8. Schwerdtfeger, W., 1984: Weather and Climate of the Antarctic. *Időjárás 89*, 116.

1986: 9. Barry, R. G. and Chorley, R.J., 1985: Atmosphere, Weather and Climate. *Időjárás 90*, 381.

10. Houghton, P.P., 1985: Handbook of Applied Meteorology. *Időjárás 90*, 251.

1987: 11. Glaciers, ice sheets, and see level effect of a CO_2-induced climatic change. U.S. Dept. of Energy, Washington, D.C. 1985. *Időjárás 91,* 51.
12. Lockwood, J.G., 1986: World Climate Systems. *Időjárás 91,* 381.
1988: 13. Götz G. és Kaba M., 1986: A havi és évszakos éghajlati előrejelzések elméleti alapjai és gyakorlati módszerei. OMSZ. Kisebb Kiadványai 59. *Időjárás 92,* 307-308.
1989: 14. Brázdil, R., 1986: Variation of Atmospheric Precipitation in the C.S.S.R. with Respect to Precipitation Changes in the European Region. Univ. J.E. Purkyno, Brno, 170 p. *Időjárás 93,* 305.
15. Das, P. K., 1986: Monsoons. WMO, No. 613., Geneva, 156 p. *Időjárás 93,* 370.
16. Lamb, H.H., 1988: Weather, Climate and Human Affairs. Routledge, *Időjárás 93,* 371.
1990: 17. Pfister, Ch., 1988: Klimageschichte der Schweiz 1525-1860. Verlag Paul Haupt, Bern, *Időjárás 94,* 308.
1991: 18. Bach, W. and Jain, A.K., 1991: From Climate Crisis to Climate Protection. Greenpeace Germany, Univ. Münster, 86 p. *Időjárás 95,* 309.
19. Klima - Umwelt - Mensch (Climate, Environment and Man). Günther Flemming, G., Gustav Fischer Verlag, Jena, 1990. 158 p. *WMO Bulletin 40, No. 2,* 178.
1992: 20. Rambler, M.B., Margulis, I. and Fester, R. (eds), 1989: Global Ecology. Towards a Science of the Biosphere. Academic Press, London, 216 p. *Időjárás 96,* 43.
1994: 21. Frakes, L.A., Francis, J.E. and Syktus, J.I., 1994: Climate Modes of the Phanerozoic. Cambridge Univ. Press, 272 p. *Időjárás 98,* 206.
1997: 22. Hervé Le Truet (ed.) 1996: Climate Sensitivity to Radiative Perturbations. Physical Mechanism and Their Validation. Springer-Verlag, NATO Advanced Science Institutes Series 43, 330 p. *Időjárás 101,* 65-66.
23. Schönwiese, C.D., 1995: Klimaänderungen. Daten, Analysen, Prognosen. Springer-Verlag. 226 p. *Időjárás 101, No. 1,* 66.
1998: 24. Yoshino, M., Domrös, M., Douguédroit, A., Paszinsky, J. and Nkemdirim, L. (eds.), 1997: Climates and Societies - A Climatological Perspective. Kluwer Ac. Publishers, 419 p. *Időjárás 102.,* 133-134.

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MICROCLIMATE OF KARSTIC DOLINES

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Összefoglalás - A karsztos területek formaképzésében és fejlődésében meghatározó tényező a klíma. A mikroklíma a karsztok geoökológiai folyamataiban játszik fontos szerepet. A tanulmány a karsztos dolináknak - a karsztok fagyzugainak - speciális mikroklímáját mutatja be, különös tekintettel a különböző tengerszintfeletti magasságokban elhelyezkedő dolinák mikroklímájának különbözőségeire és hasonlóságára.

Summary - Climate is determinant factor of the formation and development of karst surfaces. Microclimate plays an important role in the karstic geoecological processes. This work highlights the specific microclimate condition of karstic dolines as the frost pockets of karstland with special attention to the differences and similarities in the microclimates of dolines in different elevation.

Key words: microclimate, microclimate of karst dolines, air- and soil temperatures

INTRODUCTION

Climate is a determinant factor of the formation and development of karst surfaces. Amount of precipitation is the most important one of all climatic factors, as the magnitude of solution is essentially defined by it. Today, however, a new trend, namely the study of karstic geoecological systems, has got into focus besides classical karst-research.

For these investigations, the knowledge of the microclimate of karstic environment is not sufficient as the changes of the karstic geoecological system take place near, and right below the surface in the soils, and through these changes the dynamics of the system is modified. It is microclimate that plays an important role in this process. My studies of microclimate today already constitute apart of the exploration process of the climate-soil-vegetation system.

My work highlights the specific microclimatic condition of karstic dolines as the frost pockets of karstland, paying a special attention to the differences and similarities in the microclimates of dolines in different elevations above sea level (*Bárány-Kevei*, 1985).

METHODS

The field microclimate investigations were performed in a doline in the Aggtelek Karst and Bükk Mountains. Between 7 and 9 July in 1998, we examined microclimate in one of the grassy dolines of the Lusta Valley on the Bükk Plateau, and between 13th and 16th July 1988, we performed observations of microclimate in the juniper grove of the Aggtelek Karst. The air temperature was measured by Assmann-type aspiration psychrometer, while soil temperature was measured by mercurial-soil-thermometer in depths of 2, 5, 10, 20 and 30 cms. Observations were performed in every hour by day and night. The instrumental measurement was supplemented by visual perceptions. The microclimatic measurements were made under two different weather conditions. The measurings in the Bükk Mountains began on a clear day; it was followed by a wet day and then by clear night. A more favourable weather situation prevailed at the time of the microclimatic measurements in Aggtelek; therefore, the warm up processes of the daylight can be studied better here.

RESULTS

Temperature as the most important climate element depend on radiation. Radiation provides energy operating in the geoecosystem. The quantity of energy transmitted or reflected back to the atmosphere depends on the quality of the surface which intercepts the radiation. Nevertheless, as the majority of the Hungarian karstlands is covered by soil and vegetation, a significant portion of the energy radiated on the surface is generally absorbed. Convection of heat penetrates into deeper layers and gets onto the rock surface by the favourable conductivity of the rock-bed which influences the intensity of the solution processes especially at the division lines of rocks. The energy yield of solar radiation depends on the duration of insolation, cloudness and the limitation of the horizon. The angle of slope is significantly modified by the impact of exposition in the insolation period.

In addition to the culmination height of the sun, the solar spaciousness also plays a role in the warming and cooling of the negative surface forms (depressions), which changes during the year.

Dolines create an independent tertiary microclimatic space (*Wagner*, 1964) in the karst plateaus or in dry valleys because of their specific morphological features. The microclimatic space better can be appointed by their closeness and slope surfaces of different exposition. Characteristic microclimatic processes occur on the slopes, the brim and bottom of dolines which are under the influence of the whole doline but which affect the ecological processes independently in space and time.

During the day, the space of doline is filled by air of a rather higher temperature exchanged only by local turbulent air-movements. In the rise of temperature and cool down processes of slopes differences in their magnitude and time are indicated in accordance with the radiation conditions. The energy yield of solar radiation depends on the geographical latitude, the duration of insolation, the horizon limitation as well as on cloud cover at any region. The amount of radiation per surface unit is significantly modified by the exposition and angle of the slope in dolines. The steeper and more northerly exposed the slope, the higher is its radiation deficit. Moreover, insolation is most intensive on the slopes of southern exposition during daylight. However, typical characteristics of the daily pattern of radiation that the slopes with eastern exposure receive more intensive radiation from sunrise to 9 a.m. than the one with southern exposure. During the summer months, the slopes of northern exposure are also in more favourable insolation situation in the early morning and evening hours than the slope of southern exposure. The afternoon hours insolation is more intense on the slopes of western exposures. With negative forms in the depressions of dolines, self-shading exerts an important modifying effect on insolation. The early shadow-impact also contributes to the heat deficit of the southern slopes. The heat excess of the morning hours is determinated by the early onset of horizon limitation. From the early morning hours the slope of southern exposition is already in selfshade.

It is well-known that daily air temperature pattern derives from the northerly and southerly exposition of slopes (*Fig. 1*). The air temperature is warmer by 4-5°C in the warming-up period on the northern slopes (southern exposition) than on the southern slopes (northern exposition). Concerning to the absolute values of air temperature, no significant difference can be shown in the east-west cross-section (*Fig. 2*). On the other hand, difference is shown at the occurence times of maximum and minimum temperatures. Maximum temperature occurs between 9 and 11 a.m. on the east-facing slopes but it occurs between 1 and 3 p.m. on the west-facing slopes. This characteristic temperature pattern has an important effect on the soil and plant-ecological processes. In accordance with this, the different species establish themselves on different slopes, and the ecological indices of plants are formed as a function of this.

At night a "cold air lake" fills the lower layers of the doline (*Fig. 3*). The radiation minimum was minus 3°C during the night of 9th July in the plateau doline of the Bükk Mountains. Two types of phenomenons developed during the examinations:

One type is the phenomenon when cold air lake accumulates at the bottom of the doline and dew or hoar - frost is formed. The other type is when thick fog develops and the temperature will be higher at the bottom of the doline than on the slopes. The formation of the cold air lake hinders the undisturbed growth of the doline vegetation. This phenomenon can be measured well in the case of dolines covered by trees, where the several meter-high pine trees of the doline brims are of the same age as the slowly-growing pine seedlings not taller than one meter at the doline bottoms.

The daily pattern of soil temperature follows the changes of the daily air temperature with a phase delay in compliance with the exposition conditions and the shadow impact. During the day, the south east-faced slope in the upper layers of soil whereas in the lower layers the south-faced slope is warmer. Warming up begins first on the north-faced, then on the east-faced slopes. Following this, the surfaced slope warms up more than the west-faced slope does

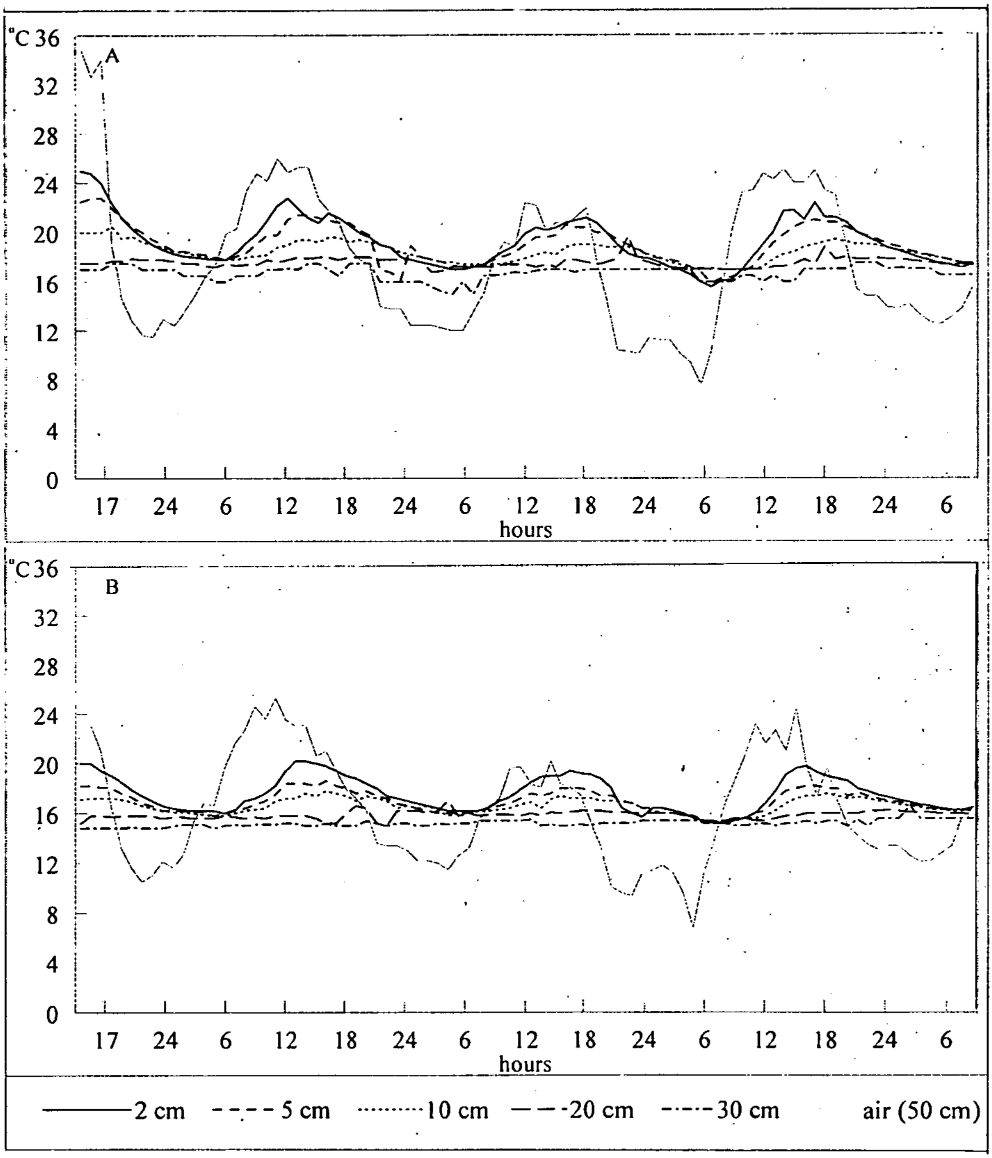

Fig. 1 The course of the soil and air temperature on the northern (A) and southern (B) slope

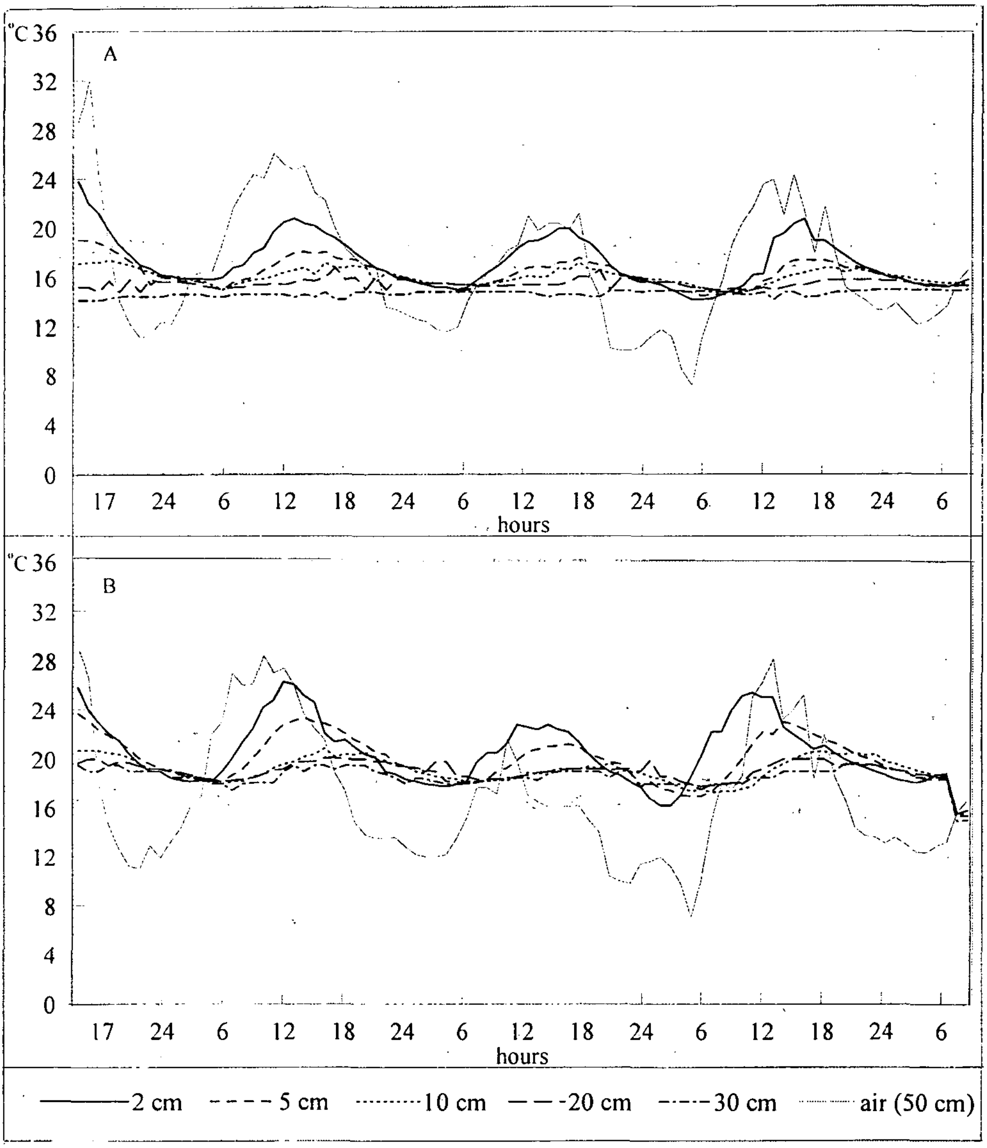

Fig. 2 The course of the soil and air temperature on the eastern (A) and western (B) slope

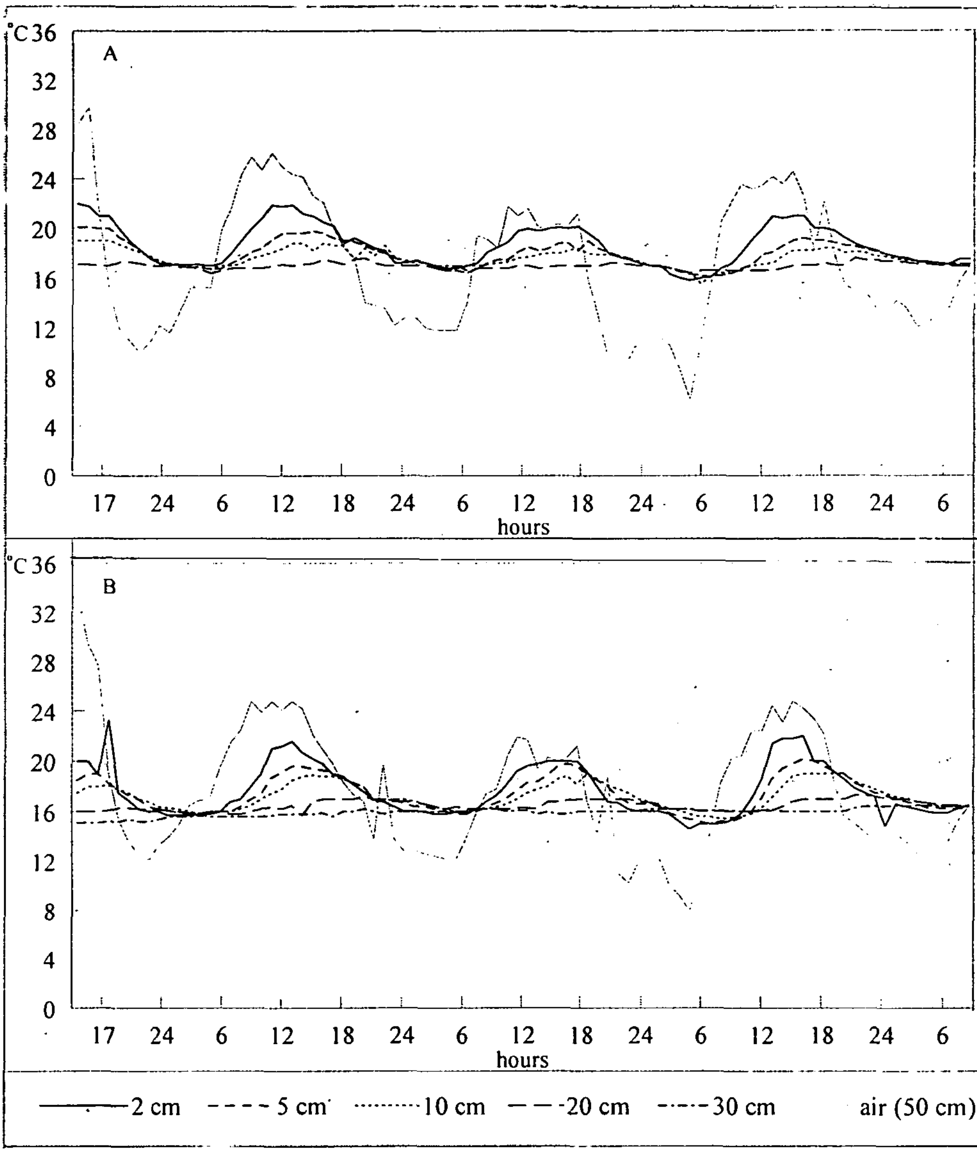

Fig. 3 The course of the soil and air temperature on the bottom (A) and brim (B) of doline

with a somewhat lower temperature maximum.

The coldest one is the southern slope. Phase delay is the greatest towards the deeper layer of the soil (*Fig. 4*). Phase delay in the different soil horizons is well indicated by the diagram which defines the active surface movements in the soil. In both areas in a depth of 30 cms, the day and night temperature waves are levelled off and only some tenth °C of differences are indicated between the warming up during the day and at night. In this layer, there are no significant changes in the different parts of the day. The temperature diagram already reflects the isotherm-state on the different slopes from microclimatic aspect.

It was also shown by the investigations that daily amplitudes of soil temperature decrease more according to the increase of the elevation above sea level than air temperature amplitudes. This is doubly true for soils covered by forest. This raises attention to the fact that consideration should be given to the identical composition of stocks when examining air and soil temperatures.

Our investigations were carried out on different karst surfaces, and reflected on characteristic temperature conditions. On rock-lawns and in the woods the difference between the maximum values of air temperature increase along with the elevation above sea level, but

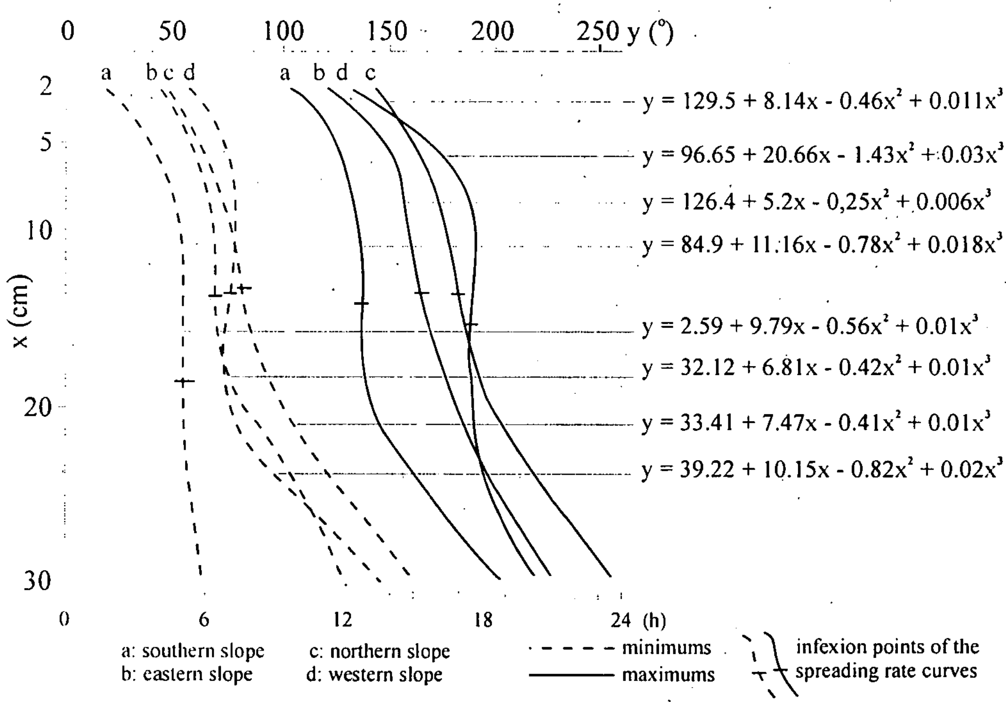

Fig. 4 Regression curves of migration of maximums and minimums in the soil

the diversion of the minimum temperatures decrease. Air temperature in the open meadow and the forest was higher at lower elevation during the day and lower at night. This means that in this case the extreme temperature values result in a greater amplitude that at higher elevations.

The basic difference between the climate of grassland and forest is the fact that the air temperature in grassland is higher during the day and lower at night than in the forest. The soil of meadows, however, is of a higher temperature both during daylight and at night than that of forests. This peculiarity is definitely in correlation with the phenomenon that the shadowing in this part prevails all day and the conduction of heat is slow. However, at night, a double cold air level is formed, one at the tree stratum as at the primarily active level and one at soil level, as the colder and denser air sinks down to the soil. With the increase in elevation above the sea level, the microclimate of dolines becomes more independent. Extremes in temperature are greater in the Bükk dolines than in the ones in the Aggtelek Karst.

SUMMARY

The climate of dolines significantly differs from the climate of the adjacent areas both in the course of daylight warm up and night cooling down.

1. The warm during the day is divergent on the different slopes. In addition to the great difference in temperature between the north- and south-faced slopes, the time difference between the occurences of maximum temperatures on the east and west-faced slopes in rather important from the vegetation aspect. On the east-faced slope, maximum occures at 10 a.m. and at 3 p.m. on the west -faced slope, which results a significant difference in the composition of the vegetation.

2. Cold air lake is a result of the night cooling down, which causes temperatures below 0°C, and induces a rather extreme microclimate along with the strong day warming up. This is also of great significance from the aspect of vegetation growth. This is manifested by a slower growth of vegetation.

3. The difference between minimum temperatures decreases, and it increases between the maximum temperatures with the increase of elevation above sea level. The type of vegetation importantly influences the microclimate. A more extreme microclimate develops in open dolines than in the wooded ones.

4. The temperature differences affect not only the vegetation but also the microbial activity of the soils. According to my observations, the condition of dampness and the temperature comply best with the bacterial activity on the west and northwest-faced slopes. For the strong insolation of the south-faced slopes are high temperatures and low dampness. The desiccation of soil causes the significant enrichment of bacteria population. This also means, from the point of an ecological system, that the decomposition of organic material and material transportation will become slower than on other slopes. The daylight differences of insolation on the various slopes are not compensated by the night emission, because the cold air lake, formed by the sinking cold air, appears in the temperature inversion. This microclimate

pecularity results an inversion of the vegetation pattern as well. Plants of smaller stature develop at the bottom of dolines than at the higher brims.

REFERENCES

Bárány-Kevei, I., 1985: Ökologische Untersuchung der Karstdolinen unter besonderer Berücksichtigung des Mikroklimas. *Acta Geographica Szegediensis 35*, 109-130.
Wagner, R., 1964: Lufttemperaturmessungen in einer Doline des Bükk-Gebirges. *Zeitschr. für Angewandte Meteorologie 5, Heft 3-4.*, 192-199.

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SPATIAL AND TEMPORAL VARIATIONS OF THE PALMER DROUGHT SEVERITY INDEX IN SOUTH-EAST HUNGARY

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Összefoglalás - Havi száraz és nedves anomáliák térbeli és időbeli jellemzőit elemezzük a Körös-Maros köze (gyakorlatilag Csongrád és Békés megye) területén, amelyet a termesztett növények nagy területi aránya jellemez. A nedvességi viszonyokat a Palmer-féle aszályossági index (PDSI) felhasználásával számszerűsítjük. A Palmer-modell számításait az 1951-1990 évek (főként a tenyészidőszakra kiterjedő) havi adatsoraira végeztük el a térség 17 állomására. Az alapvető statisztikai jellemzők, ill. a térbeli és időbeli korrelációk megállapítása mellett faktoranalízis segítségével alrégiókat is meghatároztunk, amelyeken belül a PDSI értékek hasonló fázisban ingadoznak. Vizsgáltuk a nyári félévben a térségen belül fennálló egyidejű korrelációk szorosságát, valamint a kiszáradási folyamat kezdetén (áprilisban) megfigyelt állapot hatását a rákövetkező hónapok PDSI értékeire. A hosszabb, 1881-1990 évek idősoraira elemeztük a lassúbb, egyirányú változásokat, valamint a teljes időszak átlagától szignifikánsan eltérő szakaszok hosszát.

Summary - Spatial and diachronic characteristics of monthly dry and wet anomalies are examined in the Körös-Maros Interfluve Area (in the practical calculations, Csongrád and Békés counties, on the Great Hungarian Plain), characterized by high proportionality of managed vegetation. Assessment of humidity conditions is performed by employing the Palmer Drought Severity Index (PDSI). Palmer's model is applied to monthly data (mostly in the vegetation period) for the period of 1951-1990 at 17 stations of the region. Besides computation of basic statistics and determination of the spatial and temporal correlations, factor analysis is also employed to define subareas in the region, inside of which PDSIs covary in time. Synchronous correlations between the stations of the region and the effect of April conditions on the following months PDSI values are also investigated. Long-term, unidirectional changes and also the length of periods are demonstrated, exhibiting averages which are significantly different from that case in which the whole period of 1881-1990 is covered.

Key words: Palmer Drought Severity Index - time and space correlations - factor analysis - long-term climate variations - Körös-Maros Interfluve Area - Hungary

1. INTRODUCTION

There has been an increasing concern about the observed climate variations since the preindustrial period. The distribution of world agriculture shows an adaptation to the present-day climate patterns, but this situation could change in relation to the likely global warming (*IPCC, 1996*).

Environmental and economic effects of the climate variations can be apparent first of all, through the changes of natural water supply, river discharges, average crop yields, as well as natural vegetation. Hence, a new chapter in landscape evaluation is indicated by the recognition that climate is subject to changes, also on a relatively short term. Its alterations considerably affect several processes of the landscape system. A major temperature increase greatly controls the heat and water budget of each landscape and has fundamental impacts on agriculture. On a longer time scale, a new balance of water and heat, as key factors of the surface formation, may affect morphological features of landscapes, too. Besides that, apart from global trends, climate of Hungary inclines to shorter or longer aridity and to irregular distribution of the annual precipitation.

2. THE KÖRÖS-MAROS REGION

The region, selected for the investigation is the Körös-Maros Interfluve Area (*Fig. 1*), as a medium-sized landscape (in practice, a somewhat broader area, namely Csongrád and Békés counties), which has always been characterized by high proportionality of managed vegetation. Recently, 79 % of the 8,650 km^2 productive land (which is 88 % of the total geographical area) is arable, whereas the agricultural area covers 93 % of the productive land. Proportion of inhabitants employed in agriculture is about 200 % of the national average. Hence, the investigated area is covered, in overwhelming majority, by seasonal vegetation, which is highly vulnerable to climate variations and also to the non-climatic conditions of plant management.

The plain is part of the Maros-Tisza-Körös region which consists of young sediments. The territory of this geo-morphological area is 5,000 km^2. Comparing to the neighbouring physical geographical lands, this region has "ridge" character. Consequently it is due to be named "Békés-Csanádi" ridge, as well. The total territory, together with the additional regions of both counties, is approximately 10,000 km^2. The selection of the region has also been motivated by the recent definition of a National Park in the area and by the

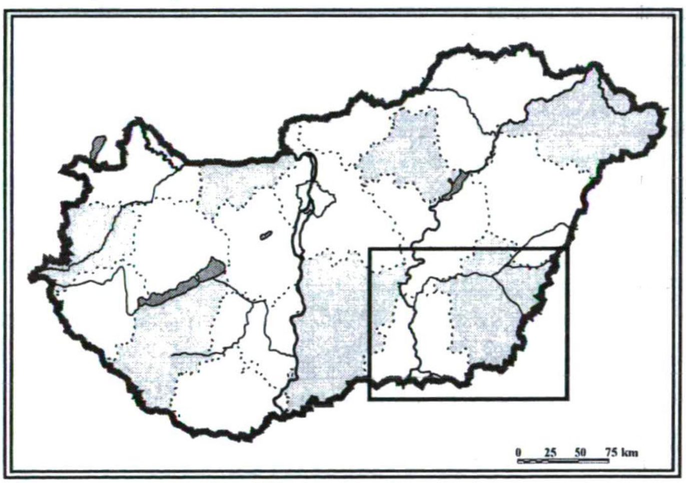

Fig. 1 The location of restricted area

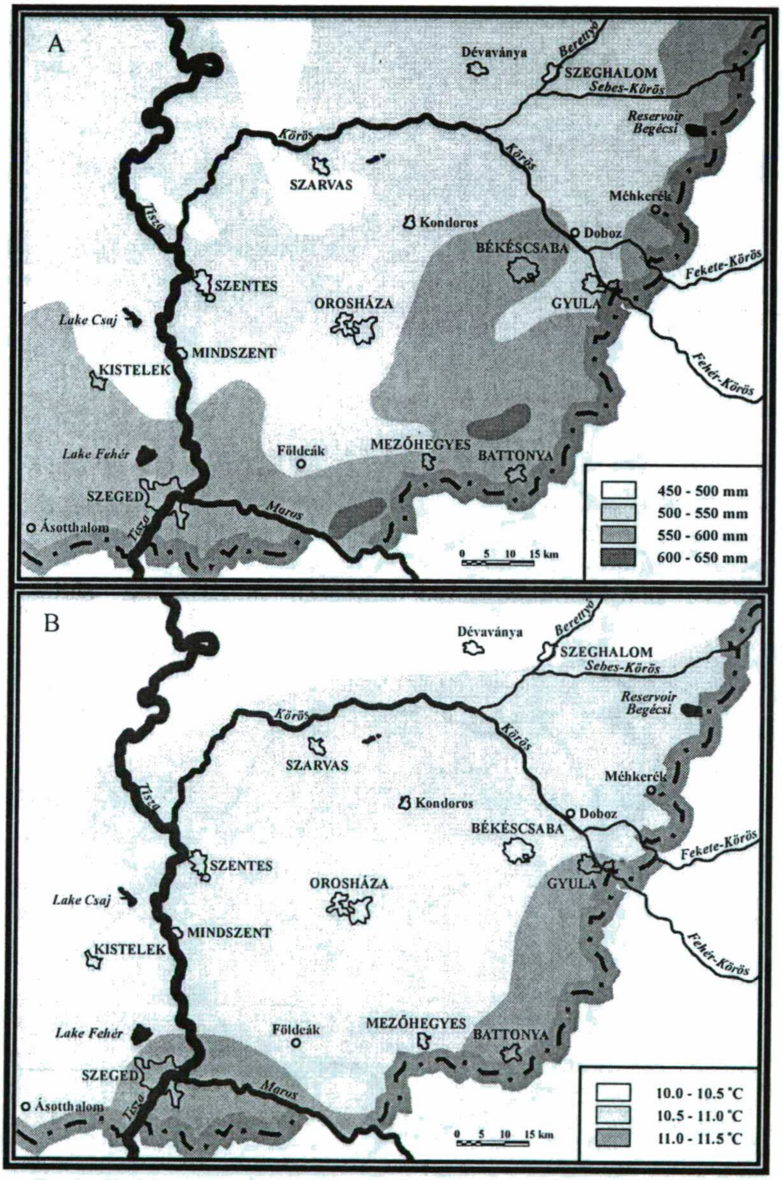

Fig. 2a-2b Climatic distribution of annual precipitation totals (A) and annual mean temperature (B) in the Körös Maros region

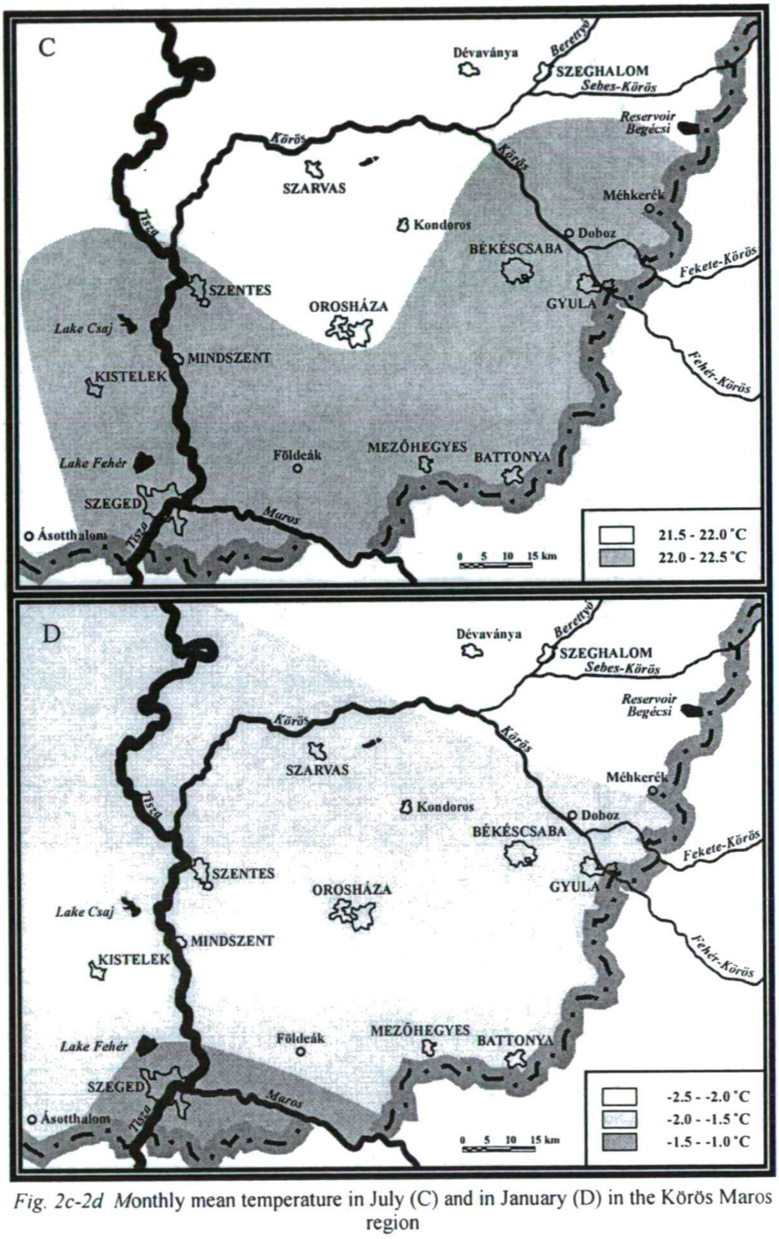

Fig. 2c-2d Monthly mean temperature in July (C) and in January (D) in the Körös Maros region international coopearation called Danube - Maros - Tisza Euroregion, as well.

The effect of the isolated Transylvanian mountains, in addition to the typical low-land climate characteristics, can also be observed in the climate of the region. The spatial distribution of precipitation is fairly changing. The precipitation amount increases from northwest towards southeast. The annual average precipitation is about 550-600 mm in southeast, even over 600 mm at some places. On the other hand, it is less than 550 mm in the most part of the region moreover, less than 500 mm in the northwestern part of the Körös-Maros region (*Fig. 2a*).

On the basis of these differences two climatic zones can be experienced in this region: the northwestern part is dry with hot summer, while the southeastern part is only moderately dry with similarly hot summer. The annual mean temperatures are shown in *Fig. 2b* (*Kakas*, 1960). The annual mean maximum temperature in this region is the highest in Hungary (*Fig. 2c*). The mean temperature of the coldest month is below 0°C, that is to say the region shows continental character (*Fig. 2d*).

Loose soils, which are permeable or semipermeable to water, do not make possible development of permanent watercourses on the surface. As compared to the annual mean temperature (10.5-11.0°C), the annual mean precipitation amount is far from the optimum. The outflow coefficient is between 3-5 %. The yearly amount of evaporation is regularly higher than that of precipitation. Consequently the aridity index is generally higher than 1. Some years are characterized with extreme aridity which correspond to semi-desertic conditions (*Makra et al.*, 1986).

The medium-sized region investigated (first of all its southwestern part) is extremely inclined to drought which causes the most serious damage in agriculture. However, irrigation is prevented by the lack of water. On the other hand, difficulties in connection with inland waters should also be mentioned. Although the region examined is characterized by scarcity of water, regularly in spring inland waters appear to some extent.

Inland waters in a given catchment area are surplus waters appearing either on the surface or in cracks of the soil, which raise difficulties to developing of plants (*Pálfai*, 1988). Appearance of inland waters is changeable in time and space, since they may come into being on the one hand in dry periods on the other hand hardly only in polder areas.

Soil formation factors here are favourable to the development of chernozem. The most fertile chernozem soils of Hungary can be found in this region. Development of various chernozems, under much the same climatic conditions, is directed by geological structure and hydrographical factors. Characteristic soil types in the region are shown in *Table 1*.

3. THE PALMER DROUGHT SEVERITY INDEX

There is no universal quantitative definition of droughts. In the present study, drought is considered as a meteorological anomaly characterized by a prolonged and abnormal moisture deficiency (*Palmer*, 1965; *Dalezios et.al.*, 1991). Nevertheless, a distinction should also be made between hydrological drought and agricultural drought. Specifically, hydrological drought can be considered as a period during which the actual water supply is less than the minimum water supply necessary for normal operations in a particular region. Agricultural drought is characterized in terms of crop failure and exists when soil moisture is depleted so that crop yield is reduced considerably.

Table 1 Soil types at the meteorological stations examined

Geographic coordinates		*Station*	*Type of soil*
latitude	**longitude**		
46°12'	19°47'	Ásotthalom	sandy coarse soil
46°16'	21°03'	Battonya	solonetzic meadow chernozem
46°40'	21°07'	Békéscsaba	meadow chernozem with salt accumulation in the deeper layers
47°01'	20°58'	Dévaványa	meadow soil
46°43'	21°13'	Doboz	meadow soil
46°17'	20°30'	Földeák	meadow chernozem (the term "meadow" is related to hydromorphic character)
46°39'	21°16'	Gyula	meadow soil
46°26'	19°50'	Kistelek	humous sandy soil
46°45'	20°50'	Kondoros	lowland chernozem
46°46'	21°24'	Méhkerék	meadow solonetz
46°19'	20°49'	Mezőhegyes	lowland chernozem
46°30'	20°11'	Mindszent	meadow alluvial and alluvial meadow soil
46°34'	20°40'	Orosháza	lowland chernozem
46°52'	20°32'	Szarvas	meadow chernozem with salt accumulation in deeper layers
46°15'	20°10'	Szeged	solonetzic meadow; meadow, alluvial soil
47°01'	21°10'	Szeghalom	meadow soil
46°39'	20°15'	Szentes	meadow soil

The immediate meteorological causes of drought involve a number of factors. A stable high-pressure air-mass with descending air and low humidity is relatively free of clouds. If this air mass stagnates or moves slowly across an area because of atmospheric circulation patterns, the region, over which it lingers, will receive substantial sunshine and generally dry air with little or no rain. Once established, this condition has a tendency to persist, resulting in drought. Although a single drought is a phenomenon of shorter time scales, the frequency of drought can vary on decadal or longer scales, especially at low geographical latitudes.

To detect the onset of meteorological droughts and assess their severity, an "objective" index is used, namely the Palmer Drought Severity Index (PDSI). The PDSI is one of the few general indices which does address some of the elusive drought properties such as intensity, onset time and end time. Although the PDSI is referred to an index of meteorological drought, the procedure considers precipitation, evapotranspiration, and soil moisture conditions, which are determinants of hydrological drought and, indirectly, of agricultural drought (*Palmer*, 1965; *Alley*, 1984; *Karl*, 1986). In addition, the PDSI is standardised for different regions and time periods which is a necessary requirement for the areal assessment of droughts.

The basic concepts and steps for computing the PDSI are presented here. The whole procedure is described by *Palmer* (1965).

Step 1: Hydrological Accounting. The computation of the PDSI begins with a climatic water balance using long series of monthly precipitation and temperature records as inputs. An empirical procedure is used to account for soil moisture storage by dividing the soil into two arbitrary layers. The upper layer is assumed to contain 25 mm of available moisture at field capacity. The loss from the underlying layer depends on the initial moisture content as well as on the computed potential evapotranspiration (PE) and the available water capacity (AWC) of the soil system. In the present calculations of PDSI, AWC values of 170 - 220 mm are used according to the soil types, presented in *Table 1*. Runoff is assumed to occur, if and only if, both layers reach their combined moisture capacity, AWC. In addition to PE, three more potential terms are used and they are defined as follows: Potential Recharge (PR) is the amount of moisture required to bring the soil to its water holding capacity. Potential Loss (PL) is the amount of moisture that could be lost from the soil by evapotranspiration during a zero precipitation period. The Potential Runoff (PRO) is defined as the difference between the potential precipitation and the potential recharge.

Step 2: Climatic Coefficients. This is accomplished by simulating the water balance for the period of available weather records. Monthly coefficients are computed as proportions between climatic averages of actual versus potential values of evaporation, recharge, runoff and loss, respectively.

Step 3: CAFEC Values. The derived coefficients are used to determine the amount of precipitation (P) required for the CAFEC (Climatically Appropriate For Existing Conditions), for instance "normal" weather during each individual month.

Step 4: Moisture Anomaly Index. In each month, the difference between the actual and CAFEC precipitations is an indicator of water deficiency or surplus for that month at the studied area. This is expressed as D=P-P. These departures are converted into indices of moisture anomaly as Z=K(j)D, where K(j) is a weighting factor for the month j which takes into account also the spatial variability of the departures (D).

Step 5: Drought Severity. In the final step the Z-index time series are analyzed to develop criteria for the beginning and ending of drought periods and a formula for determining drought severity. The following empirical expression for drought severity is used:

$$X_j = 0.897X_{j-1} + Z_j/3 \quad (1)$$

where Zj represents values of the moisture anomaly index for the dry intervals and Xj is the value of PDSI for jth month. The classification of weather using PDSI is given by *Palmer* (1965) as a stepwise gradation from PDSI < -4 (extreme drought) to PDSI > +4 (extreme wet). At *Fig. 2a* and *2b* fluctuation of the PDSI can be seen in the period of 1881-1990. The ensemble or the 12 parallels indicate the PDSI values of the individual months. It is worth to note that these monthly values fluctuate rather parallelly at the intra- and interannual time scales. Consequently, legends are omitted at *Fig. 3a* and *3b*.

4. SPATIAL VARIATIONS AND SHORT-TERM FLUCTUATIONS

Short-term variability is analysed for 11 stations of the Körös-Maros Region (Szeged, Szentes, Szarvas, Békéscsaba, Földeák, Mezőhegyes, Orosháza, Mindszent, Kondoros, Gyula, Battonya) as well as six other stations (Kistelek, Szeghalom, Ásotthalom, Dévaványa, Méhkerék, Doboz) situated in the vicinity of the strictly defined target area for the period of 1952-1985. These calculations include some basic statistics of the distributions including also the test for normality, as well. Spatial and temporal correlations aim to characterise how variations in this relatively small area are interrelated between each other and which part of the year is mostly responsible for the water availability anomalies of the vegetation period. Spatial relations are more thoroughly analysed by spatial factor analysis with the intention to determine objective subregions by applying the PDSI.

4.1 Basic statistics

In principle, PDSI is a non-seasonal characteristic of water availability, but it is worth checking if independence of season really fulfilled for the basic statistical parameters, for example average, standard deviation and standard skewness. In the following, these parameters of PDSI are analysed in four months, namely in April, June, August and October of the vegetation period.

Table 2 indicates that for the averages the assumed universality is fairly valid: deviations from the mean are not large in the different months. In case of standard deviations, however the picture is not so unequivocal. The minimum among these four months is in June at each station and the maximum occurs mainly in August. Although the differences between the highest and lowest standard deviations are themselves non-significant (according to the F-test), the identical course of the values in the four months at the four stations should be considered as regular.

For standard skewness there is an increasing tendency from negative values in April to the positive ones towards the end of the vegetation period. Negative standard skewness values in April (with the exception of Szarvas) indicate that lower (relatively dry) values are more

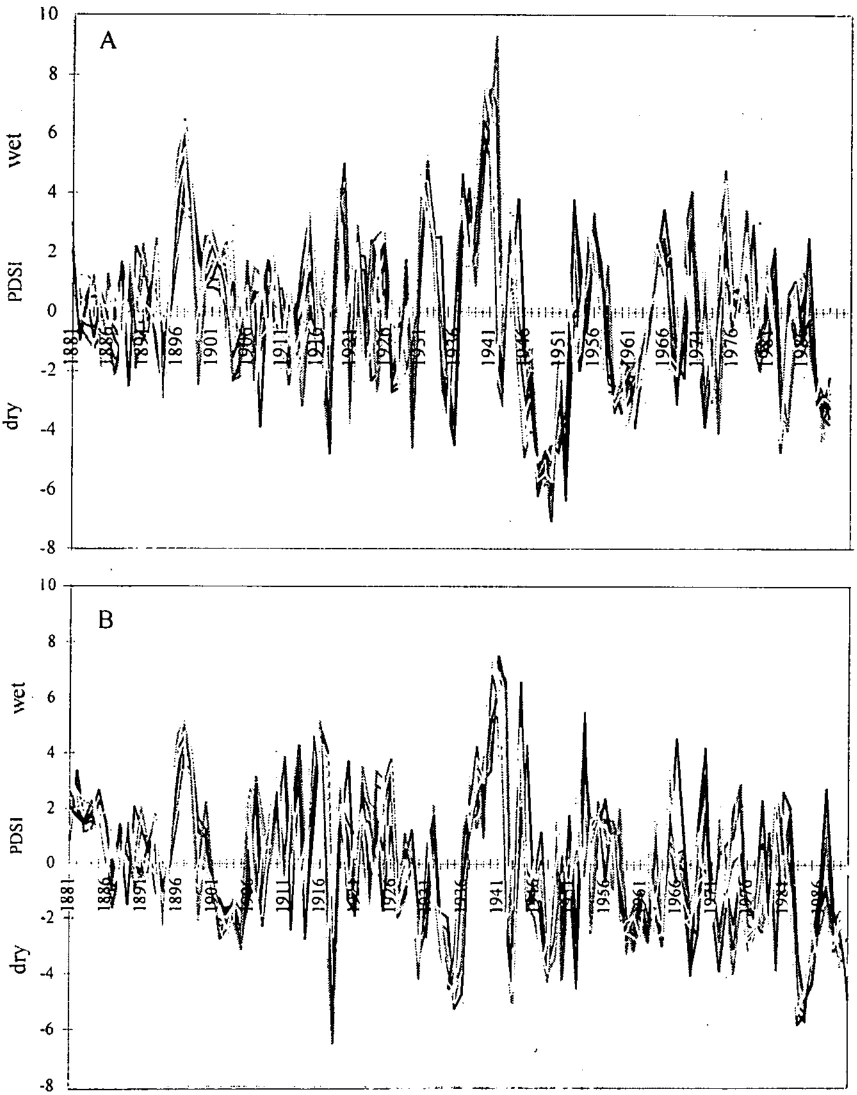

Fig. 3a-3b The parallel fluctuation of the monthly PDSI values at the intra- and interannual time scales, 1881-1990. A) Szeged; B) Szarvas frequent, but high extremes are more severe. In those months with positive skewness the situation is generally the opposite: high (wet) extreme values are more frequent, but strong droughts occurred in the investigated 1951-90 period.

Table 2 Basic statistics of the PDSI and results of normality tests (probability in %)

	Battonya				*Méhkerék*				*Szarvas*				*Szeged*			
	April	*Jun*	*Aug*	*Oct*	*April*	*Jun*	*Aug*	*Oct*	*April*	*Jun*	*Aug*	*Oct*	*April*	*Jun*	*Aug*	*Oct*
Mean	-0.00	-0.23	-0.04	0.19	-0.17	-0.13	0.06	-0.01	-0.32	-0.00	0.13	-0.01	-0.02	-0.11	+0.00	-0.01
St. dev	1.75	1.57	1.95	1.85	1.68	1.62	1.95	2.05	1.60	1.48	1.98	1.79	2.09	1.75	1.94	1.86
Skewn.	-0.33	0.21	0.04	0.10	-0.50	0.20	0.47	0.46	0.14	0.33	0.47	0.94	-0.87	-0.39	0.08	0.93
K-S test	99	25	68	94	92	68	67	64	39	23	90	53	93	99	81	34
χ^2 *test*	55	69	35	10	12	4	49	8	2	5	31	45	20	63	5	5

This cyclicity also supports that in the followings we analyse the PDSI statistics separately for the selected months.

As far as the normality of the distributions is concerned, the Kolmogorov-Smirnov (K-S) test shows that, normality is a likely assumption for PDSI, although probability of this decision is rarely higher than 90 %. According to the χ^2-test, normality is not so unequivocal. From the 16 investigated ones the normality is fulfilled in 10 cases, but the rest is distributed rather irregularly between the sites and the months of the vegetation period. Without monthly separation, the series exhibit definitely irregular, non Gaussian distribution (*Mika et al.*, 1994)

4.2 Space and time correlations

Spatial correlations are computed for synchronous monthly PDSI values of four stations, Szeged, Szarvas, Méhkerék and Battonya, situated more or less regularly at the four "edges" of the region. Analysing spatial correlations (*Table 3*) corresponding to identical months of the year, they demonstrate moderate strength of connections. The correlations are always positive and significant at the 1 % significance level, which is not surprising at all. On the other hand, the numerical values between 0.43 and 0.83 suggest that even in this small region (10,000 km^2, as already indicated) the drought/wetness conditions may vary, likely due to the spatial irregularity of precipitation.

If comparing the values in the different months, one can establish that they are relatively high in April and August (0.65 - 0.83), but lower (0.43 - 0.70) in the climatically wet June and the highly variable October. This means for these two months that in some years the dry or wet periods occur in the region, but not in other cases.

Another interesting question, related to dry or wet anomalies, is how strongly the conditions at the end of previous cold half-year determine those in the forthcoming vegetation period. In this respect, correlations between April and other months are displayed below the diagonal of *Table 3.* The 5 % correlation threshold is 0.34, which is surpassed at three stations from the four investigated cases for June (r = 0.38 - 0.47) and reached in one station for August. Hence, PDSI values of October and August are determined mainly by the moisture balance of the vegetation period, itself.

Table 3 Spatial (synchronous) and temporal (retarded) correlations of the PDSI in four selected stations of the Körös-Maros Region

		BATTONYA				***MÉHKERÉK***				***SZARVAS***				***SZEGED***			
		April	***Jun***	***Aug***	***Oct***	***April***	***Jun***	***Aug***	***Oct***	***April***	***Jun***	***Aug***	***Oct***	***April***	***Jun***	***Aug***	***Oct***
BATTONYA	***April***					0.73				0.77				0.78			
	June	0.38					0.46				0.52				0.55		
	August	0.34						0.70				0.67				0.71	
	October	0.02							0.70				0.49				0.64
MÉHKERÉK	***April***									0.83				0.72			
	June					0.43					0.51				0.55		
	August					0.22						0.65				0.70	
	October					0.18							0.44				0.57
SZARVAS	***April***													0.77			
	June									0.26					0.61		
	August									0.06						0.69	
	October									-0.09							0.43
SZEGED	***April***																
	June													0.47			
	August													0.22			
	October													-0.06			

We should note that these correlations are naturally lower than those published by *Mika* (1996) for other stations of Hungary, since those values were increased by the low-frequency variations of the 110 years series, while the present correlations characterise only 40 years.

4.3 Regionalisation by factor analysis

One of the best methods studying time series data for a large number of stations or grid points, where strong spatial and temporal correlation prevails, is *Factor Analysis* (see e.g. *Bartzokas and Metaxas*, 1993). One of the main benefits of this method is the reduction of the initial variables to much fewer uncorrelated ones, namely the factors. In this way, regions can be defined where, for any point within each region, the analysed meteorological variable covaries. Each original variable, P_i, i=1, 2, ..., n, can be expressed as $P_i=a_{i1}F_1+a_{i2}F_2+...+a_{im}F_m$ $(m<n)$, where F_j, j=1, 2,...,m, are the factors and a_{ij} are the loadings. One important stage of this method is the decision for the number (m) of the retained factors. On this matter, many criteria have been proposed. In this study, the *Guttman criterion* or *Rule 1* is used (*Bartzokas and Metaxas*, 1993) which determines to keep the factors with eigenvalues > 1, and neglect the ones that do not account for at least the variance of one standardized variable. Another vital stage in this analysis is the so-called rotation of the axes (factors). This process achieves a discrimination among the loadings which makes the rotated axes easier to interpret. In this analysis the *Orthogonal Varimax Rotation* has been applied, which keeps the factors uncorrelated. In general, there is no guarantee that the evaluated factors represent dynamically existing entities, but, as with any statistical tool, it is important to determine whether or not the results have any physical meaning.

Factor analysis defined different numbers of subareas in the different months of the year. The eigenvalues and the percentages, explained by the retained and rotated factors for PDSI for each month are shown in *Table 4.* It is found that the retained factors explain 71 - 78 % of the total variance exhibited by all initial variables. The number of retained factors varies between 1 and 3. The first case means that there is no internal structure within the region as far as the 17 stations are able to represent it. One region is found mainly in the relatively low-precipitation periods of the year (January, February, March, April, August and December). Two subregions occur in May, July, September, October and November. In June, the analysis yields 3 regions, in good coincidence with the phase of the annual maximum of precipitation.

Table 4 The significant eigenvalues and the total percentage of variance explained by the retained and rotated factors

	Jan	*Feb*	*Mar*	*Apr*	*May*	*June*	*July*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
1	13.2	13.2	13.2	13.4	10.8	9.9	10.8	12.1	11.1	12.2	11.5	13.2
2					1.9	2.0	1.2		1.4	1.1	1.1	
3						1.0						
Expl. var.	78	78	78	79	75	76	71	71	74	78	74	78

Although the method of Factor Analysis derives the regions from similarities and differences on time scales of climate fluctuations, and also, the regions differ considerably from one month to the other, it is worth displaying the obtained regions, as well (*Fig. 4a-4f*). Central parts of the subregions are indicated by the 0.8 factor loading isolines (except for one region in June, for which this value is only 0.6).

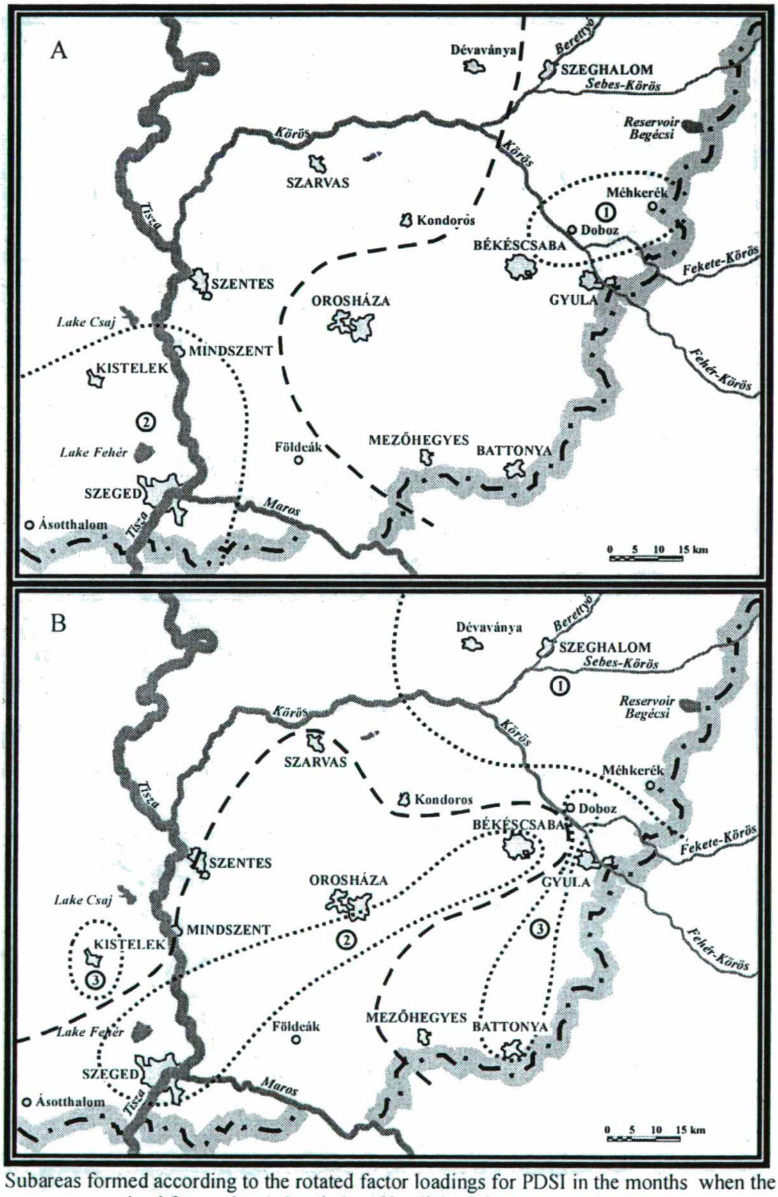

Fig. 4a-4b Subareas formed according to the rotated factor loadings for PDSI in the months when the number of retained factors is >1. Isopleths of loadings 0.8 are usually indicated.
(A. May; B. June. In June that of 0.6 for the third separating region is also drawn.)

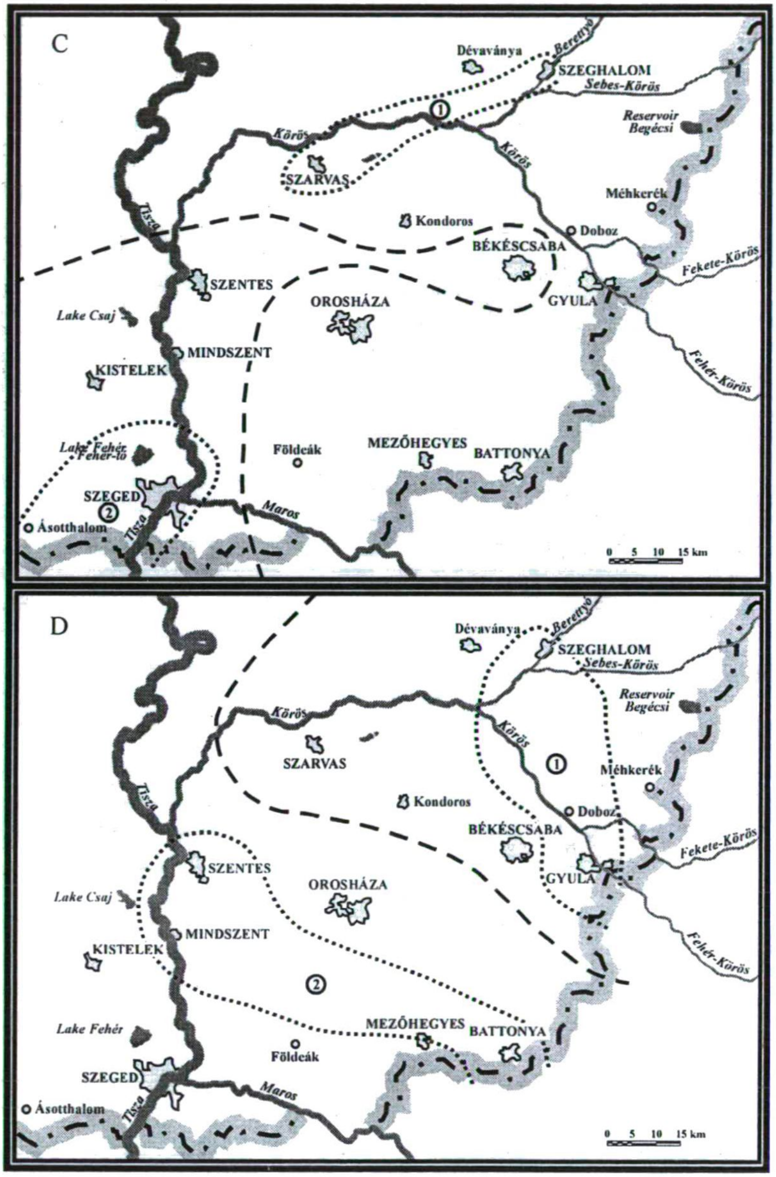

Fig. 4c-4d C. July; D. September

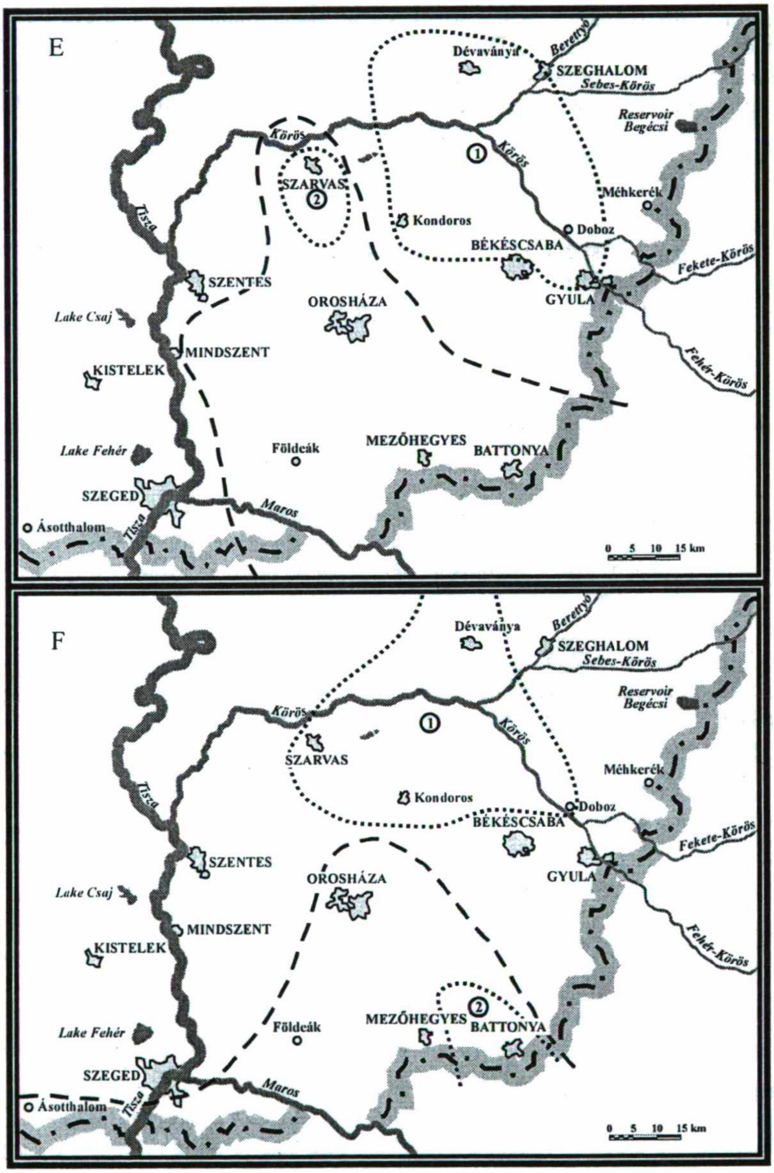

Fig. 4e-4f E. October; F. November

The regions are realistic in statistical sense. This means, that they are not direct consequences of the method, itself. This consequence is supported by the fact that in the half of the calendar months the number of regions is different. On the other hand, this fact also indicates that the obtained regions may not serve so objective basis of a landscape classification.

5. ANALYSIS OF LONG-TERM VARIATIONS

Two questions are statistically investigated in the four months-indicators of the vegetation period, for example. April, June, August and October:
i) When did significant linear trends occur during the investigated 110 years period?
ii) When did the time averages significantly differ from that in the whole period?

In both cases, Student's t-test was applied in different design. Before going into the answer of these questions, however, let us demonstrate the smoothed course of monthly PDSI during the investigated 1881-1990 period (*Fig. 5a-5b*). The applied filter is the 11 years' moving average.

In both series there is a pronounced long-term cyclicity which occured after the depression of short-term fluctuations by the 11 years moving average smoothing. PDSI at Szeged exhibited nearly 36 years' cyclicity during this 110 years period. At Szarvas, the same feature exhibit 30 years' cycles. Statistical significance of these periods requires further analyses on the original series.

The long-term, decreasing tendency of the PDSI is generally similar at the two nearly situated sites, especially at Szarvas. Another common feature is that PDSI values of the four different months vary parallel with each other at the two sites until cca. 1960. After 1960, PDSI values of April exhibit steeper decreasing tendency than those of the other months. Compared to Szeged, this difference is more characteristic in Szarvas.

5.1 Local trend analyses

Significancy of linear trends during any subperiod within the 110 years is checked by Student's t-test, as follows. Let us have the variable of Student distribution,

$$t = (b - \beta) / s_b \qquad (2)$$

Where β - the real (unknown) regression coefficient,

b - empirical regression coefficient, estimated from the finite sample,

s_b - standard deviation of the empirical estimate from the regression coefficient, b.

The zero-hypothesis is that $b = \beta = 0$, i. e. the empirical regression b does not significantly differ from 0. The statistical decision concerning this hypothesis is performed on the basis of the knowledge of the t-distribution (included into tables, in practice). The following analysis of the significance is performed at the 1 % significance level, considering that the appropriate degree of freedom is *n - 2*, where *n* is the number of elements in the sample. If the t-value,

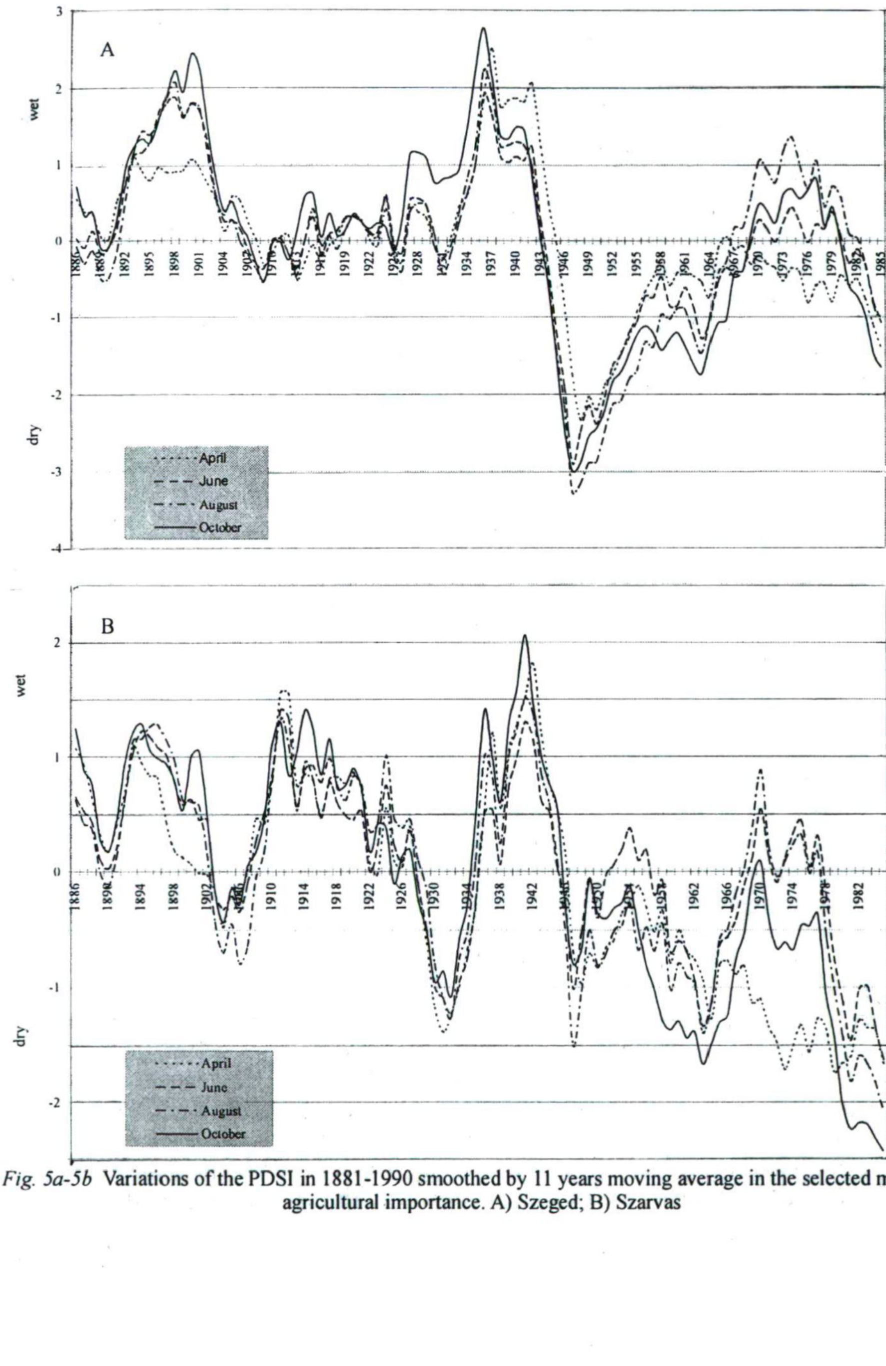

Fig. 5a-5b Variations of the PDSI in 1881-1990 smoothed by 11 years moving average in the selected months of agricultural importance. A) Szeged; B) Szarvas calculated by (2), is higher than the given threshold of the t-distribution, we consider b to be significantly different from 0. Otherwise, it is not. This test has been performed for all possible 3-110 years subperiods between 1881 and 1990.

In this way, the following can be established (*Table 5*). Linear trends of monthly PDSI series are generally significant only for relatively short 3-12 years sequences. It is also remarkable that the number of significant trends is only two, at both stations. For the longer sequences, the interannual variance is too high to allow significance of monotonous linear changes in the local series. In the table, sequence of significant periods is set in diachronic order. If comparing signs of the first and second significant periods, one can establish that they are completely different at the two sites. Decreasing (drying) trends follow the opposite ones in the first three investigated months at Szarvas, but at Szeged the situation is the opposite. This difference between the sites remains valid in October with a change of signs. Significant periods of the same sign are not much similar either in the four months or at the two sites. This means that such short sequences are yielded rather by random interannual fluctuations than by the long-term trends.

Table 5 Subperiods with significant PDSI linear trends in 1881-1990

	April	*June*	*August*	*October*
SZARVAS	1959-1967: 9 yr (+)	1934-1940: 7 yr (+)	1935-1937: 3 yr (+)	1896-1903: 8 yr (-)
	1982-1989: 8 yr (-)	1954-1965: 12 yr (-)	1954-1965: 12 yr (-)	1983-1989: 7 yr (+)
SZEGED	1908-1915: 8 yr (-)	1896-1908: 13 yr (-)	1955-1960: 6 yr (-)	1962-1965: 4 yr (+)
	1959-1967: 9 yr (+)	1960-1966: 7 yr (+)	1959-1962: 4 yr (+)	1984-1989: 6 yr (-)

5.2. A special application of Student's t-test: significant deviations of time-slices

The aim of this section is to identify subperiods' averages of which are significantly different from the 110 years mean. These subperiods were much drier or wetter than that. The point of the method is to determine the start and the termination of the significant periods. This is done for data for which the significance is still valid, irrespectively to that, which years would yield the strongest difference (i. e. among the significant ones). This search has been performed by a special case of Student's t-test, applied to detect differences between averages of non-independent series (*Makra et al.*, 1999). The significance tests have been performed at the 1 % significance level.

Contrary to those found in the previous section, length of these subperiods is much longer, which already characterizes the climate change time-scales (*Table 6*). In the four analysed months of the vegetation period, the following significant differences were detected:

It is remarkable that the number of significant periods is maximum two, at both stations. In the table, sequence of significant periods is defined in diachronic order. The signs of the first long-term periods are positive, and those of the second ones are negative in each investigated month. This means that relatively wet periods preceded the drier ones during the 110 years.

Positive (wet) deviations at Szeged occurred in April between 1887-1943 (57 years), in June between 1881-1941 (61 years), in August between 1883-1941 (59 years) and in October between 1881-1941 (61 years). At Szarvas, the wet deviations appeared between 1881-1946 (65 years) in April, between 1939-1941 (3 years !) in June, between 1881-1981 (101 years !!) in August and between 1881-1957 (77 years) in October.

Negative (dry) long periods occurred at Szeged between 1946-1990 (45 years) in April, between 1946-1990 (45 years) in June, between 1946-1990 (45 years) in August and between 1942-1990 (49 years) in October. At Szarvas, dry periods appeared between 1926-1990 (65 years), no such period existed in June, short dry period was found significant between 1982-1990 (9 years) but a fairly long one between 1928-1990 (63 years) in October. These results are in harmony with those ones according to which relative frequency of warm-dry years are incerasing in the Great Hungarian Plain between the period of 1901-1990 (*Tar*, 1993).

The experienced similarity between the long-term anomalies of identical sign in the consequtive months and at the two sites suggest that these long sequences are already yielded the long-term trends. Furthermore the decadal-scale deviation periods were wet in the first and dry in the second phase of their appearance.

This result is in full coincidence with the conclusions elaborated in a previous review paper (*Mika et al.*, 1995), declaring that the climate of the Hungarian Great Plain became drier in the more recent decades, according to series of native references.

Table 6 Subperiods with significantly different averages of PDSI from that of the full data set in 1881-1990.

	April	*June*	*August*	*October*
SZARVAS	1881-1946: 65 yr (+)	1939-1941: 3 yr (+)	1881-1981: 101 yr (+)	1881-1957: 77 yr (+)
	1926-1990: 65 yr (-)		1982-1990: 9 yr (-)	1928-1990: 63 yr (-)
SZEGED	1887-1943: 57 yr (+)	1881-1941: 61 yr (+)	1883-1941: 59 yr (+)	1881-1941: 61 yr (+)
	1946-1990: 45 yr (-)	1946-1990: 45 yr (-)	1946-1990: 45 yr (-)	1942-1990: 49 yr (-)

6. DISCUSSION

There is one possible shortcoming of the computations that may have led to non-representative conclusions. This questionable detail may be the inhomogeneity of the local temperature series that could affect the potential evaporation calculations for PDSI, especially in summer, when the inhomogeneities were the largest (Szentimrey, 1996). Even for temperature series of the chief meteorological stations this important problem could not have been found a final resolution yet.

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REFERENCES

Alley, W. M., 1984: The Palmer Drought Severity Index: limitations and assumptions. *Climate Appl. Meteor. 23*, 1100-1109.

Bartzokas A. and Metaxas D.A., 1993:Covariability and climatic changes of the lower troposphere temperatures over the Northern hemisphere. *Il Nouvo Cimen. 16C*, 359-373.

Dalezios N. R., Papazafiriou, Z.G., Papamichail, D.M. and Karakostas, T.S., 1991: Drought assessment for the potential of precipitation enhancement in northern Greece. *Theor. Appl. Climatol. 44*, 75-88.

Horváth, Cs., 1994: Geographical assessment and natural values of the planned Körös-Maros National Park (in Hungarian). *MSc Thesis*, JATE Szeged, manuscript.

IPCC, 1996: *Climate Change 1995. The Science of Climate Change.* Contribution of Working group I to the Second Assessment Report of the IPCC (*Houghton, J.T. et al.*, eds.) Cambridge Univ. Press, 570 p.

Kakas, J. (ed.), 1960: *Climatic atlas of Hungary* (in Hungarian). Akadémiai Kiadó, Budapest.

Karl, T. R., 1986: The sensitivity of the Palmer Drought Severity Index and Palmer's Z index to their calibration coefficients including potential evapotranspiration. *J. Clim. Appl. Met. 25*, 77-86.

Makra, L., Kiss, Á. and Abonyiné-Palotás, J., 1986: Climatic and water balance components of drought and some agricultural considerations in the Southern part of the Great Hungarian Plain (in Hungarian). *Alföldi Tanulmányok*, 99-114.

Makra, L., Tar, K. and Horváth, Sz., 1999: A special case ot the Student's t-test and its application. *Int. Journal of Ambient Energy* (accepted for publication)

Mika, J., 1996: Variations of the Palmer Drought Severity Index in Hungary with respect to the global climate changes. In: *18th Conf. Danube Countries*, Graz, 123-129

Mika, J., Bartzokas, A., Dobrovolny, P., Brazdil, R., Niedzwiedz, T., Tsidarakis, L. and Dalezios, R. N., 1994: On spatial and temporal variations of drought in selected regions of central and southeastern Europe. In: (*Brazdil, R. and Kolař, M.*, eds.) *Contemporary Climatology*. IGU Symp., 15-20, 1994, Brno, Czech Rep., 395-402.

Mika, J., Ambrózy, P., Bartholy, J., Nemes, C. and Pálvölgyi, T., 1995: Climate variability and tendencies of Hungarian Great Plain: a literature survey (in Hungarian). *Vízügyi Közlemények 77*, 261–286.

Pálfai, I., 1988: Soil-born floodings in the Great Plain (in Hungarian). *Alföldi Tanulmányok 12*, 7-22.

Palmer, W. C., 1965: *Meteorological Drought.* Research Paper No 45, U.S. Weather Bureau, Washington, D.C., Feb., 58 p.

Szentimrey, T., 1996: Some statistical problems of homogenisation: break points detection, weighting of reference series. – *Proceed. 13th Conference on Probability and Statistics in the Atmospheric Sciences* 21–23 February 1996, San Francisco, California, 365–368.

Tar, K., 1993: Investigation of temperature and precipitation time series in connection with potential climate change (in Hungarian). *Acta Geographica et Geologica et Meteorologica Debrecina, Kossuth Lajos University, Debrecen,. XXXII/42*, 147-164.

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Universitatis Szegediensis, Tom. 32-33, 1999, 51-64.

SOME WEATHER EVENTS IN THE FOURTEENTH CENTURY II. (ANGEVIN PERIOD: 1301-87)

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Összefoglalás - A vizsgálat célja - egy, a korábbinál nagyobb adatbázis alapján - annak bemutatása, hogy a klímatörténeti kutatásokban az eddig talált források milyen lehetőségeket nyújtanak egy lehetséges klímarekonstrukcióhoz. A dolgozat kizárólag az egykorú, vagy közel egykorú, megbízhatónak vélt anjou-kori (1301-1387), elsősorban írott források csoportját érinti. Mivel a rendelkezésre álló adatok mennyisége nem enged meg konkrét klímarekonstrukciót az adott időszakra, így a dolgozat másik célja, hogy a bemutatásra kerülő adatokat összevetve a rendelkezésre álló, a korszakra vonatkozó európai, de különösen közép-európai adatbázisokkal, bizonyos lehetséges összefüggéseket állapítson meg.

Summary - The aim of this study is to provide more evidence for a possible climatic reconstruction of the Hungarian Kingdom in the period of 1301-87, on an increased database of fifty, mainly contemporary sources. Another goal is to present the European, but especially the Central-European conditions at the same time in order to find some parallels between the European database and the data referring to the areas of the former Hungarian Kingdom.

Key words: climate history, weather events, floods of rivers, written sources, charters, 14th-century Hungary

SOURCES AND DATABASE

In this study, a database of contemporary written sources and archeological evidence were provided which refer to some weather events and also to some cases connected to the hydrological and climatic conditions of certain parts of the former Hungarian Kingdom from the period between 1301 and 1387. In addition, on the basis of the medieval database of the surrounding territories, another aim is to find possible connections, parallels between these databases and the records (mainly charters) reflecting on some weather events in fourteenth-century Hungary. Thus, this article is a continuation of an earlier study which was written on the same subject, but dealt with a shorter time period from 1338-1358 (*Kiss*, 1996). In this case, for a longer time-period, around one-third (about 10000) of the remaining charters from the Angevin period was investigated, mainly those which have been published in different collections. Moreover, the summary (regesta) collection of the

Hungarian National Archives was examined, and the available contemporary information on the hydrological conditions of the two largest lakes in the Carpathian Basin: Lake Balaton and Lake Fertő (Neusiedlersee) in the afore-mentioned period were also collected. This data collection consists of fifty direct or indirect records (*Table 1*) contained useful and reliable (in case of uncertainty, I noted it with a question mark in *Table 1*) information related to such weather and other environmental events as deep snow, frost, too great or unusual floods etc. Nevertheless, there are only few narrative sources, namely some Hungarian and non-Hungarian chronicles, which also contain a very limited amount of further information. On the other hand, the information content of the whole database is quite different from a database from a diary or a chronicle, in which the most remarkable events were usually emphasised. Here, we have separate sets of information: each data came from different charters (or, in some exceptional cases, from chronicles). Moreover, charters often provide quite accurate information about one particular day: the day on which a perambulation was made. From these charters, we learn little about the actual conditions (e.g. the beginning or the end of the event), only the fact that it exsisted on a given day. Most (80%) were connected to certain weather events, and a smaller group of sources (20%) rather reflect on the changing conditions in the previously mentioned period. (*Fig. 1*)

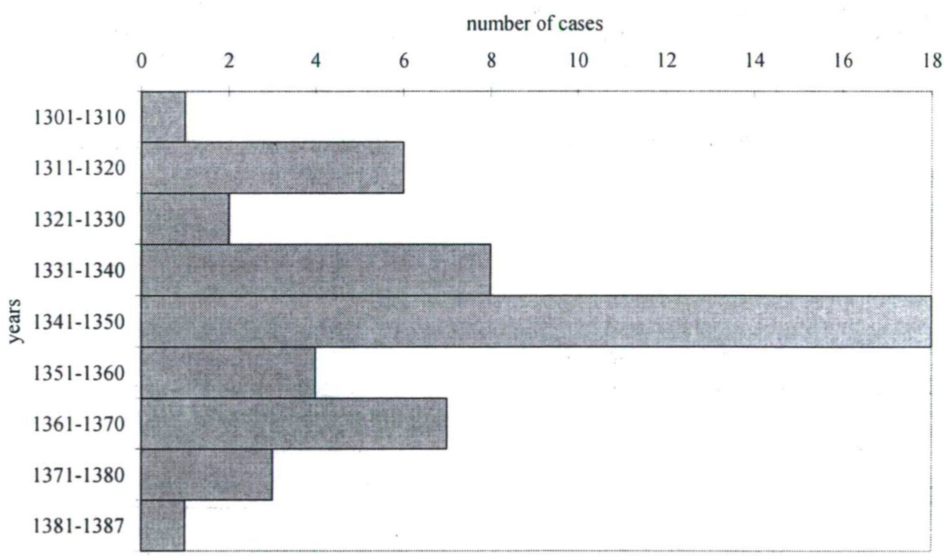

Fig. 1 Temporal distribution of the weather events between 1301 and 1387 in the Carpathian Basin

The spatial distribution of the fifty data is quite uneven: more than half of the information refer to the northern part of the kingdom while, for example, there are almost no sources related to the eastern and southeastern areas of the country (*Fig. 2*). This fact may be related to the relative lack of remaining contemporary sources in the southern and southeastern regions of the Carpathian Basin. The time distribution of the sources is also uneven: twenty of the fifty data are connected to events and conditions of the 1340s, which decade was also quite unfavourable in many other parts of Europe.

Although the number of sources and the type of events and conditions do not yield enough evidence to allow a proper reconstruction for any time in the fourteenth century, it is still important to compile a database in order to open up the possibility of a future comparison between the recorded weather and hydrological events of the former Hungarian Kingdom and other Central-European databases. Also, it could provide a basis for a future, larger collection of reliable sources refering to the medieval climatic conditions in certain parts of Hungary.

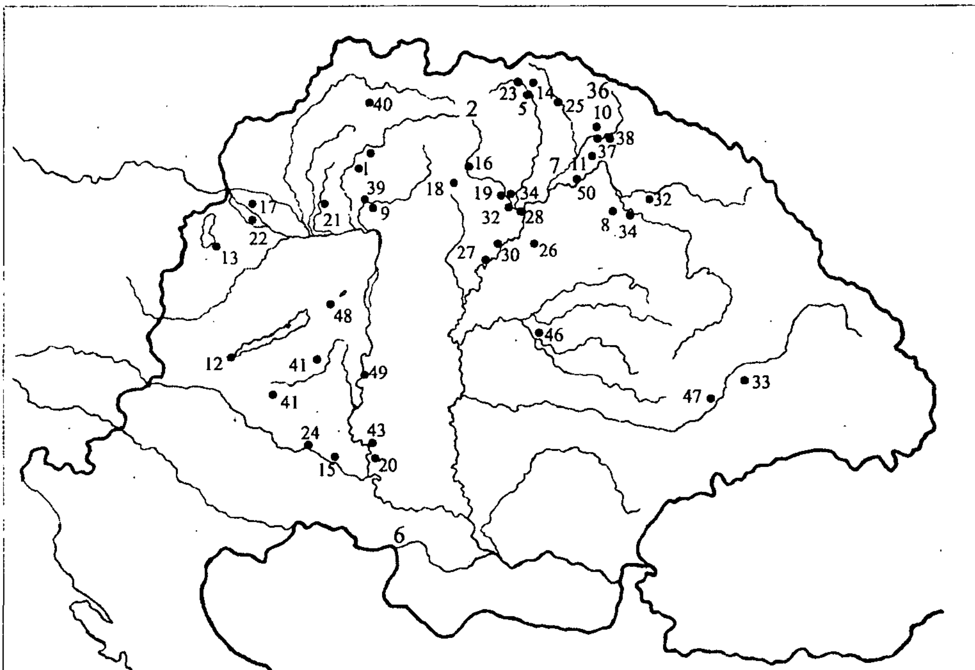

Fig. 2 Spatial distribution of the weather events between 1301 and 1387 in the Carpathian Basin

Andrea Kiss

THE CLIMATE OF EUROPE IN THE FOURTEENTH CENTURY

The fourteenth century was a part of a transitional period between the 'Medieval Warm Epoch' and the 'Little Ice Age' when the first signs of the climatic deterioration became obvious. The first years of the 1300s were the turning point for the climatic changes in most parts of Europe. The abandonment of marginal regions in Europe, which had earlier become inhabited during the Medieval Warm Epoch, began at the end of the thirteenth century and increased throughout the fourteenth century. From the 1300s, wet years were more frequent in the first decades of the century which caused poor harvests and famines particularly in the western and northern parts of Europe which were the most overpopulated regions at that time. Another sign of these changes was that a growing number of mines in the Alps and the northern mountains of Central-Europe had to be closed by the miners because of increasing amounts of water and the more extreme weather conditions (*Lamb,* 1988. 48). The average number of frosty days in May multiplied in England (*Lamb,* 1982. 168), and the population in the northern parts of Norway started to decrease dramatically (*Lamb,* 1982. 168). At the same time, shortly after 1300, a new, drier period began in the European territories of Russia and the severe winters became more frequent in the northern half of the Great Eastern-European Plain (*Lamb,* 1982. 196).

The period between 1310 and 1347 was especially wet in Western Europe (*Lamb,* 1988. 58). Because of these circumstances, the tree-line was 100 or 200 m lower in the higher mountains of Europe (*Lamb,* 1982. 195). During these wetter and cooler times, there were two periods which were enormously unfavourable for the population of Europe. Between 1303 and 1328 cold winters prevailed (*Pfister et al.*, 1996. 100), while the following decades until the mid 1350's average winters were predominant without real extremities. (*Pfister et al.*, 1996. 101) In 1342, the trade routes of the Vikings were replaced to the southern regions of the Atlantic ocean because of the great mass of ice around Iceland and other northern islands. Because of the unusal weather conditions, the harvests of these years were poor and from 1348 until 1352 one third of the population of Europe died from the plague and famine. The glaciers of the Alps attained their greatest medieval extent around 1350. After this time glaciers began to decrease again (*Lamb,* 1988. 44).

While in the western and northern parts of Europe wet climatic conditions dominated until the 1370s, in the Czech Kingdom dry summers became more common between 1360 and 1380. Winter temperatures of Europe were quite variable in the period of 1355-1375 with an extremelly severe winter of 1363/4 (*Pfister et al.*, 1996. 101); in the Czech areas, mild winters dominated from 1340 until 1390, though between 1340 and 1370 these winters were not only unusually mild but quite dry as well (*Brázdil and Kotyza,* 1995. 161). Russia lived through one of the driest times in her history during the period between 1360 and 1380 (*Borisenkov-Paseckij,* 1983. 91-92). The winters of the last decades of the century were close to the temperature averages of the 'Little Ice Age' without great extremities (*Pfister et al.*, 1996. 102).

In conclusion we can say that the climate of the fourteenth century was cooler and wetter in some parts, but more disturbed than in earlier times. This century was especially different from the previous centuries because of the new climatic effects on food production which were followed by a sharp decrease of population.

COMPARISON TO THE AVAILABLE SOURCES OF THE NEIGHBOURING AREAS

In comparison with European, but especially Central-European conditions, some parallels can be presumed, which should provide results after further examination. As a basis of comparison, the data, based on contemporary sources from the books of P. Alexandre and R. Brazdil and O. Kotyza, were used. Applying the database of *Table 1*, I refer only to those events for which I could find any comparison or even contradiction in the database from the surrounding territories.

No. 3-5.: There are at least three available sources which refer to river floods (even the Danube) in 1316, not only for Hungary but also for other parts of Central Europe such as Poland, as well as the Czech, the German territories and Poland (*Brazdil and Kotyza*, 1995. 111). High prices in the Upper-Hungarian area was also mentioned for 1316 in a charter written in 1342.

No. 7.: The serious freezing over of the Bodrog river could happen between 1316 and 1322. In the surrounding countries, the winter of 1317 was long and cold (*Alexandre*, 1987. 744). From this information we may presume that this event occured in 1317. On the other hand, the presence of King Charles Robert in the vicinity of the river - because of the political circumstances of the time (*Kristó*, 1988. 52) - would suggest that this happened in the next winter of 1317- 8 which was not really cold in other parts of Europe (*Pfister et al.*, 1996. 104)

No. 8.: The inundation on the upper part of the Tisza river is quite important as it occured in the second half of February in 1325, and covered quite large areas in the northeastern part of the Great Hungarian Plain. It is interesting to note that there was a flood in on the Ohre river in the Czech Kingdom (*Brazdil and Kotyza*, 1995. 112, 234) "which was caused by a quick thaw of snow in the mountains".

No. 11-13.: The winter of 1334 and 1335 was very hard and snowy in the Czech territories (*Brazdil and Kotyza*, 1995. 235) and this was the prevailing condition in other parts of Europe (*Pfister et al.*, 1996. 104) such as many parts of the French Kingdom (*Alexandre*, 1987. 755). Some parallels may be indicated in a charter which mentiones the fact that the flood around the 4th April, 1335 was too large: it was so serious that "the whole county of Ungvár in this area" was inundated. This large flood may also refer to the abundance of previous winter precipitation in the mountains.

The waterlevel of Lake Balaton was around 106 m above the Adriatic sea level in 1335 (today it is 105 m), but - as we know from an archaeological reconstruction - it rose quite rapidly in the fourteenth century so that researchers were able to estimate the possible waterlevel in 1335. Concerning Lake Fertő (Neusiedlersee), there is more infomation which refers to some elements in the hydrological condition of the lake including meadows "*in Fertew*" showing that the waterlevel could not have been high at that time. On the other hand, the weather reports connected to the Czech lands probably has more connection to the rising waterlevel of Lake Balaton, since both the winter and the summer of 1335 were quite cold and rich in precipitation (*Brázdil and Kotyza*, 1995. 235).

No. 19-26.: For the year of 1342, seven data could be found which referred to weather events: this is a much higher number than in any other periods of the fourteenth century. This year was also rather difficult in many parts of Europe outside of the Carpathian Basin. The winter of 1341-2 was severe with much snow and great frosts in Moravia and the Czech lands (*Brázdil and Kotyza*, 1995. 235) and high prices were mentioned although without date (*Brázdil and Kotyza*, 1995. 236).

On the 1st February, in 1342, there was an early, great flood on the Vltava, Elba and Morava rivers which appeared with warm southern winds, thaw and rain (*Brázdil and Kotyza*, 1995. 236). Three days later, on the 4th February, a data refers to another flood which occured on the Szinva river, in the lower, southern region of the northeastern Carpathians. The exact date of the beginning of this flood is uncertain, but the flooding was already occuring on the afore-mentioned day. Therefore, we can presume some parallels between the meteorological and hydrological events in these two areas. Other floods were also reported from the same year on the Zsitva (*Table 1*) and then, probably on a land, not far from the Lower-Danube (*Table 1*). Concerning the hydrological conditions of the river, it is even more possible as the winter was also snowy in the montainous parts (Alps) of the catchment area of the Danube. Moreover, the autumn floods of the Dráva river in the southwest and of the Tapoly and Ondava rivers in the northeastern part of the country were also reported which may also have certain parallels with the weather conditions of other parts of Europe.

No. 30-31.: In the spring of 1346, another great flood of the Tisza river was mentioned in a charter: this event has probable connections to the weather in certain parts of Europe (*Alexandre*, 1987. 756).

No. 34.: In the middle of January in 1349, there was a serious flood on the Tisza, which influenced large areas in the northeastern parts of the Great Hungarian Plain. Additionally, the winter in Austria was heavy in precipitation. The same was also true for Styrie and Carinthie (*Alexandre*, 1987. 247).

NO. 36.: In 1352, the king's army crossed the northeastern Carpathians, through the so called Ruthenian Mountains. Although the exact date of the event is still uncertain (end of winter, beginning of spring), during the four days, when they were crossing the mountainous area, they had to walk in deep snow which reached the saddle of the horses.

No. 40.: In the mountainous villages of the northwestern Carpathians, deep snow was described for the first part of May, 1361. The winter of 1361 was also quite severe in

Austria (*Alexandre*, 1987. 249).

No. 41-42.: The deep of snow and the severity of winter was mentioned in 1364, referring to large areas (lands in two different counties) south to Lake Balatón, in the Transdanubian region. In the same year, the winter was also severe and snowy in many parts of Europe (*Alexandre*, 1987. 249), and was mentioned as perhaps the most severe winter of the period (*Pfister et al.*, 1996. 102). These circumstances could have caused the problems in food supply and the high prices in the country, in 1364, as well (*Table 1*).

Clearly, only around half of the sources can be compared to any kind of information connected with contemporary weather conditions in the surrounding territories.

CONCLUSIONS

This database can provide good, but mainly everyday examples which makes it imposible to reconstruct the beginning, the duration and the end of given meteorological event. The amount of information is so few that reconstruction cannot be made. Many of the examples refer to hydrological events or the abundance of precipitation. Another part is connected to unusually cold temperatures. Because of the type of the source material, other types of weather events or changes could appear only exceptionally in the charters (such as high prices etc.)

Concerning the relative lack of proper narrative contemporary sources - related to the weather events of the Hungarian Kingdom - we cannot reconstruct the probable influences of the climatic changes of the fourteenth century. However, using the evidence from written sources and archaeological research, and comparing the collected data to the Central and Western European databases, some parallels can be recognised.

Table 1 Records of weather and hydrological events in Hungary in the period between 1301 and 1387

number of data	source	county	place	year	month, day	event	floods of rivers
1	AOklt. 2/296	Bars	Lehotka, Garamszent-benedek	1309	-	frequent floods	Garam
2	G. Hain Chr., 17		Szepesség	3 years around 1312	-	famine	-
3	Chron. Leob. 33-34		Hungary	1316	-	flood	Danube
4	Chron. Aulae Reg. Lib. 1/128, CM 511.		Hungary	1316	-	unusual weather, continuous rains, floods	
5	Schmauk 2/93.o.	Sáros	Pécs-Újfalu	1316	-	high prices	-
6	AOklt. 7/48	Szerém (?)	Száva river	1319	winter	vicissitudinous weather	-
7	DL 99892	Zemplén (?)	Bodrog river	Before 1322	winter	thick ice on the river	-
8	DL 96117	Szatmár	Vetés, Voja	1325	21 February	flood	Tisza, Kraszna, Tur
9	AOklt 12., DF 282744	Hont	Szántó	1328	between 8 Nov. and 2 Dec.	vicissitudinous, winter weather	-
10	DL 102897	Ungvár	Tasolya, Pálóc	1334	beginning of April	flood	Ung and its tributaries
11	AO 3/161	Ungvár	Szelmenc and this part of the whole county	1335	4 April	flood	Ung and its tributaries
12	Zala 1/294-307	Zala	Zalavár	1335	June	rising waterlevel of the Balaton	-
13	Bgl.4/87-8	Sopron	Széplak	1335		the waterlevel of the lake is not high	Lake Fertő
14	Fejér 8/4/364	Sáros	Trocsány, Cherocyna, Remete	1338	1 May	deep snow and great flood	near the Tapoly
15	AO 23/329-30	Baranya	the (ferry) harbour at Eszék	1339	bime of inundation	inundation	Dráva

number of data	source	county	place	year	month, day	event	floods of rivers
16	AO 3/597	Gömör	Csoltó, Lekenye	1339	before 31 August	flood	the waters of the Sajó and Halbokapat aka
17	Fejér 8/4/488	Pozsony	Páka	1340	25 July	too wet and muddy meadow	near the Danube
18	Kub. 2/160	Gömör	Harmac	1341	8 November	flood	Rima
19	DL 75835	Borsod	Déta, Korcs	1342	4 February	great flood	Szinva
20	DL 58509	Bács	Aranyan	1342	a day between 11 April and 7 May	floods	Danube (??)
21	AO 4/289	Bars	Besenyő	1342	25 April	inundation of waters	Zsitva
22	AO 4/284	Pozsony	Báhony, Zámoly	1342	15 September	hard times, deep snow	-
23	DL 68845	Sáros	Tarkő, Lucska, Haruncsár	1342	5 day between 21 July and 19 August	strong frost, cold weather	-
24	AO 5/68	Baranya	Vaiszló, Hirics, Luszok	1342	15 September	flood	small tributaries of the Dráva
25	AO 4/280	Zemplén	Maráza	1342	11 November	inundation of waters	Tapoly and Ondava
26	Zichy 2/58		Zámmonostor	Before 1343	-	probable floods of the previous times	Hortobágy
27	AO 4/341	Heves-újvár	Kömlő	1343	15 May	flood and hard times	Tisza
28	DL 96237	Borsod, Zemplén	Szentalbert, Kerencs	1343	13 July	flood	Sajó
29	Zichy 2/127, 130, 148		Bazza	1344		swampy, inundated land	meeler stream: in the forest of the Bodrog
30	Károlyi 1/164	Hevesúj-vár	Poroszló, Megyer	1346	20 April	great flood	Tisza (Egervize)

number of data	source	county	place	year	month, day	event	floods of rivers
31	DL 3794		Felk	1346		previous floods	Danube (??)
32	AO 5/119	Borsod	Ónod, Hidvég	1347	23 February	great floods of waters	near the Sajó
33	DL 30383	Küküllő	Dombó	1348	19 October	flood	Kis-Küküllő
34	AO 5/266	Szatmár, Bereg	Badaló, Kér	1349	13 January and the following days	floods of waters	near the Tisza and Szamos
35	AO 5/271	Gömör	Panyit	1349		too wet and swampy area	
36	Anony-mous Minorite 107		Northeastern Carpathians	1352	4 (?) days before 6(?) April	deep snow reaching the saddle of the horses	-
37	AO 6/527	Ungvár	Sislóc	1356	7 December	too great flood	Ung
38	Zichy 3/61, 67, 93, 128	Ungvár	Daróc	1357	1 May	too great inundations of waters	Ung
39	AO 7/16-9	Hont	Tarcsány	1358	20 January	winter weather, frozen ground	-
40	DL 90540	Turóc	between Nadasér and Polereka	1361	10 March	deep snow	-
41	DF 266 606	Tolna, Somogy	Tamási, Hedruh (Hedrehely)	1364	a day between 8 January and 9 February	severe winter, deep snow	-
42	Fejér 9/3/408		Hungary	1364		high prices	-
43	DL 58575	Bodrog	Csente	1366	a day between 18 March and 12 April	floods	near the Danube (??)
44	ZW 897/293	?	?	1367	13 January	flood	the catchment area of river Maros (??)

number of data	source	county	place	year	month, day	event	floods of rivers
45	DL 96425	?	Hosszúmező	1367	1 May	great flood of the waters	Tisza and its tributaries
46	DL 36825	Békés (?)	Belmeger	before 1367 (years)	-	frozen lakes	
47	DL 30706, DL 31105, DL 30398	Alsó-Fehér	Gyógy, Orbó, Enyed	1372	May	sudden rain(s), bad weather	-
48	Károly 2/682	Fejér	Sárszabadi, Székesfehérvár	1372	28 June	inundation of waters	swamps of the Sárrét area, Sár river (?)
49	DL 106183	Fejér	Halász	1377	1 July	flood	Danube
50	DL 96560	Zemplén	Rozvág, Cigánd	1381 (?)	6 (?) March	flood, bad weather	Tisza

NOTES TO THE QUESTION OF LOCALISATION

Due to the changes of the early 20th century, many of the places, mentioned in *Table 1*, can be found today in the neighbouring countries. Because of this, it is also important to give the present names of these settlements (if they exist):

Croatia:
15. Eszék = Osijek

Romania:
33. Dombó = Dâmbau
47. Gyógy = Stremt, Orbó = Gârbova de jos, Enyed = Aiud

Slovakia:
1. Garamszentbenedek = Hronský Benadik, Lehotka = Lehota
2. Szepesség = Spiš region
5. Pécs-Újfalu = Pecovská Nová Ves
9. Szántó = Sántov
10. Tasolya = Tašul'a, Pálóc = Pavlovce nad Uhom
14. Trócsány = Trocany

16. Csoltó = Coltovo, Lekenye = Lekena
17. Páka = the area of the present Vel'ká Paka
18. Harmac = Hrmavec
21. Besenyő = Bešenov
22. Báhony = Báhon, Zámoly = abandoned land near Báhon
23. Tarkő = Kamenica, Lucska and Haruncsár - abandoned settlements near Kamenica
35. Panyit = Poniata
39. Tarcsány = Horné-Semerovce
40. Nadasér = Nedozor - today it is part of Rakša, Polereka = Polerieka

Ukraine:
11. Szelmenc = Solonci - today it is part of Komarovci
34. Badaló = Badolovó
37. Sislóc = Sislovci - today it is part of Tarnovci
38. Daróc = Dravci - today it is part of Uzshorod

Yugoslavia:
20. Aranyan = abandoned land northwest to Petrovaradin

ABBREVIATIONS OF PRIMARY SOURCES

Anonymous Minorite: *Geréb, I. and Trencséni-Waldapfel, I.*, 1960: *The chronicle of the Anonymus Minorite and János Küküllei*. Budapest.
AO: *Nagy, I. and Tasnádi Nagy, Gy.*, 1878-1920: *Codex diplomatarium Hungaricum Andegavensis*. 7 Vols. (in Hungarian) Budapest.
AOklt. 2: *Kristó, Gy.*, 1992: *Cartulary of the Angevin Period: 1306-1310* (in Hungarian). Vol. 7. Budapest-Szeged.
AOklt. 7: *Blazovich, L. and Géczi, L.*, 1991: *Cartulary of the Angevin Period: 1339* (in Hungarian). Vol. 7. Szeged.
Anjou Oklt. 12: *Almási, T.*: *Cartulary of the Angevin Period: 1328* (in Hungarian). Vol. 12. Szeged. Manuscript
AOklt. 23: *Piti, F.*, 1999: *Cartulary of the Angevin Period: 1339* (in Hungarian). Vol. 23. Szeged.
Bgl.: *Lindeck-Pozza, I.*, 1985: *Urkundenbuch des Burgenlandes und der angrenzenden Gebiete der Komitate Wieselburg, Ödenburg und Eisenburg. Die Urkunden von 1328 bis 1342 mit Nachträgen von 1284 bis 1318.* Vol. 4. Vienna.
Chron. Aulae Regiae: Chronicon Aulae Regiae Lib. I. Abbati Ottonis et Petri de Zittau. Ed.: Fontes Rerum Bohemicarum. Praha, 1873.
Chron. Leobiensis: *Zahn, J.*, 1889: Chronicon Leobiensis.

DL, DF: Archives of Diplomatics (Hungarian National Archives, Collection of medieval charters)
Fejér: *Fejér, Gy.*, 1829-1844: *Codex Diplomaticus Hungariae ecclesiasticus ac civilis.* Budae
G. Hain Chr.: *Véber, K. (ed.)*, 1988: *Chronicle and annales of the Szepesség and Lőcse for the kind posterity by Gaspar Hain.* (in Hungarian) Budapest.
Károly: *Károly, J.*, 1898: *History of Fejér county.* Vol. 2. Székesfehérvár
Károlyi: *Géresi, K.*, 1882-1897: *Codex diplomaticus comitum Károlyi de Nagykároly.* 5 Vols. Budapest.
Kub.: *Kubinyi, F.*, 1888: Diplomatarium Hontense. Vol. 1. In: *Monumenta Hungariae Historica* II. Budapest.
Schmauk: *Schmauk, M.*, 1889: *Supplementum Analectorum terrae Scepusiensis.* Pars II. Szepesváralja.
Wenzel: *Wenzel, G.*, 1871-1876: *Acta extera Andegavensia.* Vol. 1-3. Budapest.
Zala: *Nagy, I. and Véghelyi, D.*, 1886-1890: *The history of Zala county. Chartulary.* 2 Vols. (in Hungarian). Budapest.
Zichy: *Nagy, I., Nagy, I. and Véghely, D.*, 1871-1931: *Codex diplomaticus domus senioris comitum Zichy de Zich et Vásonkeő* I-XII. Pest-Budapest.
Z.W.: *Zimmermann, F., Werner, C. and Müller, G.*, 1892-1981: *Urkundenbuch zur Geschichte der Deutschen in Siebenbürgen.* I-VI. Hermannstadt-Köln-Wien-Bukarest.

REFERENCES

Alexandre, P., 1987: *Le climat en Europe au Moyen Age. Contribution a l'historie des variations climatiques de 1000 a 1425, d'apres les sources narratives de l'Europe occidentale.* Ecole des Hautes Etudes en Sciences Sociales, Paris.
Borisenkov, E. P. and Paseckij, V. M., 1983: *Ekstremalnyje prirodnye javlenija v rzsskih letopisjah XI-XVII vv.* Leningrad.
Brazdil, R. and Kotyza, O., 1995: *History of Weather and the Climate In the Czech Lands I. Period 1000-1500.* Geographisches Institut ETH, Zürich.
Chernavskaya, M., 1992: *Botanical indicators of the Little Ice Age in the Russian Plain. In: Proceedings of the International Symposium on the Little Ice Age Climate.* Tokio.
Kiss, A., 1996: Some weather events from the fourteenth century (1338-1358). *Acta Climatologica Universitatis Szegediensis 30*, 61-9.
Kristó Gy., 1988: *Wars of the Angevin Period* (in Hungarian). Budapest.
Lamb, H. H., 1982, 1995: *Climate, history and the Modern World.* London.
Lamb, H. H., 1988: *Weather, climate and human affairs.* London.

Pfister, C., Schwarz, G. and Wegmann, M. 1996: Winter severity in Europe: the fourteenth century. *Climate Change 34*, 91-108.
Sági, K., 1968: The waterlevel tendencies of Lake Balaton in the mirror of the historical and cartographical data (in Hungarian). *Veszprém Megyei Múzeumi Közlemények 7*, 441-468.

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ANALYSIS OF ELEMENTAL COMPOSITION OF ATMOSPHERIC AEROSOL IN INDONESIA

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Összefoglalás - Makra László indonéziai terepi mûszeres expedíciója során, 1996-ban 7 db aeroszol mintát gyûjtött Jáva és Bali szigetén, részben tengerparti, részben nagyvárosi, sûrûn lakott környezetben. A mintákat PIXE-módszerrel analizáltuk. Ismertetjük az aeroszol minták elemi összetételét és feldúsulásukat. A minták a klór, a kén, a réz, a cink és a neodímium szignifikáns földúsulását mutatják mind Jáván, mind Balin. Míg a klór tengeri eredetû, a kén részben antropogén, jelentõs része viszont az óceánból származik, s biogén eredetû.

Summary - During a Hungarian expedition in 1996, seven aerosol samples were collected by László Makra in Indonesia, partly in the polluted air of overpopulated Javanese towns, partly in the clean air of Javanese and Balinese seashores,. The samples collected were analysed by the PIXE-method. Elemental composition and enrichment of the elements are shown in this study. As a conclusion, chlorine, sulphur, copper zinc and neodymium are highly concentrated all over the country. While chlorine can be considered of marine origin, sulphur is partly of anthropogenic partly of biogenic origin and this latter comes from the sea.

Key words: PIXE-method, elemental composition, enrichment factor, non-crustal fraction, Java, Bali

INTRODUCTION

Indonesia is situated between the mainlands of Asia and Australia and is surrounded by the Pacific and Indian Oceans. Two-thirds of the total area of Indonesia is water whereas the country itself, with its more than 13700 islands (about 6 thousand of which is inhabited), is spread out along the Equator.

Due to the structure of the islands and their geographical location, the air over Indonesia is warm and humid with near-equal daily and yearly temperatures and water vapour near to saturation at sites near sea level. The climate is almost entirely controlled by the monsoon, especially in the southern part of the country. The Northern Hemisphere winter corresponds to the wet season whereas the dry season occurs during the Southern Hemisphere winter. The region in which air, coming from the Northern Hemisphere, meets air from the Southern Hemisphere plays an important role in the weather of Indonesia. This region is known as the Intertropical Zone of Convergence. Along this region the weather is usually cloudy and rainy, and sometimes a line of cumulonimbus clouds, with tops reaching 15 km or more, can be found.

In general, the wet season prevails in the area north of the Conwergence Zone, and the dry season prevails south of it. Although the season is called "dry", this does not necessarily mean that there is no rain at all. Wet and dry seasons are distinguishable but, in general, there is no month without rainfall. In fact, according to Köppen's classification, a tropical rainforest climate predominates in Indonesia (*Landsberg*, 1969).

The Indonesian islands are situated just at the border of the Asian and Australian mainlands. Hence this is the region of frequent structural movements, consequences of which are earthquakes and volcanic eruptions. The country is usually called as the land of volcanoes. There are altogether 240 volcanoes here, from which 80 are working even nowadays. Because of the intensive volcanic activity, soil is very fertile and is full with minerals.

According to our examinations samples were taken in Java and Bali Islands. While Java is overpopulated and concentrated with heavy industry, on Bali there are no industrial sources for air pollution.

The elemental composition of atmospheric aerosol particles has been studied widely during the last three decades. Aerosols play an important role in the atmosphere, e.g. by modifying radiation, cloud and fog formation and precipitation; even they influence human health. The reason for such measurements is to estimate the environmental impact of the particles on local, regional and global scales. Among other things, samplings in the atmosphere, far from human activities, have been carried out under oceanic and continental conditions to investigate the global cycle of aerosols (e.g. *Mészáros*, 1978; *Penkett et al.*, 1979; *Adams et al.*, 1980, 1983; *Winchester et al.*, 1981a, 1981b; *Morales et al.*, 1990). On the other hand results may show characteristics of anthropogenic pollution in overpopulated cities in Asia being highly industrialised compared with background regions (e.g. *Winchester et al.*, 1981a, 1981b; *Hu et al.*, 1987; *Winchester and Wang*, 1989; *Hashimoto et al.*, 1994; *Ning et al.*, 1996; *Zou and Hooper*, 1997).

Several papers have been published about air pollution characteristics of urban and non-urban regions of Indonesia (e.g. *Zou and Hooper*, 1997; *Cohen*, 1998). According to the analysis of *Zou and Hooper* (1997), crustal dust contributes significantly to both coarse and fine fraction of aerosol in the air of Jakarta. Nevertheless few information is available on the aerosol in the air over Indonesia. Elemental composition of atmospheric aerosols was analysed in the Asian region e.g. over Lake Baikal (*Van Malderen et al.*, 1996); Northern China (*Winchester et al.*, 1981a, 1981b; *Fan et al.*, 1996); and the Loess Plateau, China (*Zhang et al.*, 1993).

One of the frequently applied techniques of elemental analytics of atmospheric aerosols is the PIXE method. Possibilities of this procedure are discussed, among other papers, in comprehensive studies of *Koltay* (1990), furthermore *Maenhaut and Malmqvist* (1992). Authors of the present manuscript applied this technique, among other papers, in *Borbély-Kiss et al.*, (1991, 1999), *Molnár et al.*, (1993b, 1995) for qualification of regional aerosols. Technical details are given in these papers.

The aim of this paper is to characterise the elemental composition of aerosol samples collected in the air over Indonesia.

SAMPLING AND ANALYSIS

Atmospheric aerosol particles were collected on Nuclepore polycarbonate filters of 15 mm diameter with pore size of 0.4 μm. After samplings, the filters were placed into small plexiglas boxes sealed carefully. The filters were kept in these boxes until their analysis in Hungary.

We collected four samples in Java and three in Bali Island (*Fig. 1*). The latter mentioned three samples were taken at Adika Sari, Bali, at the same site. Three of the samples were taken from urban areas [Jakarta, Bandung and Yogyakarta (Java Island)] and the other four samplings were performed at seashore [Carita, Labuan (sampling site No. 1.), one measurement and Adika Sari, Bali (sampling site No. 5.), three measurements]. Carita and Adika Sari (with four samples connected actually to two sites) can be considered as background areas. This means that they are not influenced directly by local pollution sources. The geographical positions and characteristics of the sampling sites are given in *Fig. 1* and *Table 1*.

Table 1 Date of samplings; geographical positions and description of sampling sites, Indonesia

Sample No.	Date	H (m)	φ (°S)	λ (°E)	Site description
1	04 May	2	6° 50'	105° 57'	Carita, Labuan (seashore)
2	07 May	7	6° 11'	106° 50'	Jakarta (urban site)
3	09 May	709	7° 05'	107° 56'	Bandung (urban site)
4	11 May	116	7° 38'	110° 34'	Yogyakarta (urban site)
5a	17 May	12	8° 41'	115° 26'	Adika Sari, Bali (seashore)
5b	19 May	12	8° 41'	115° 26'	Adika Sari, Bali (seashore)
5c	21 May	12	8° 41'	115° 26'	Adika Sari, Bali (seashore)

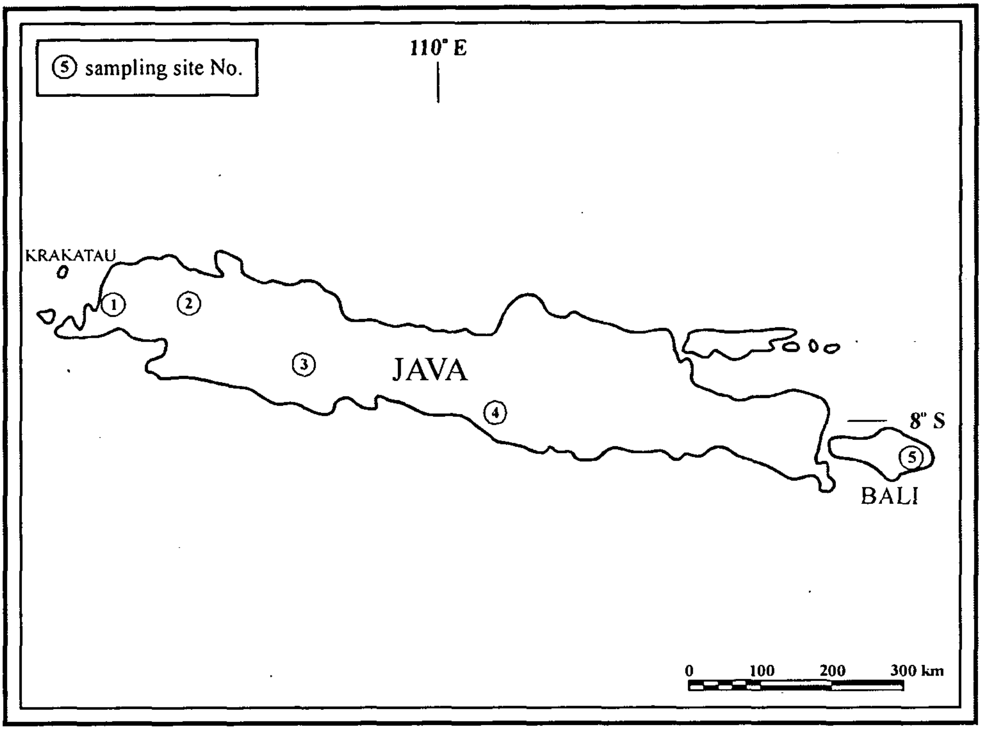

Fig. 1 Position of sampling sites in Indonesia with spatial distribution of elements enriched over ten, excluding sulphur, chlorine, copper and zinc

The sampling was performed at 1.5 m height. The filter holder was connected to a vacuum pump, which was operated at a flow rate of approximately 20 l min^{-1}. The pump was equipped with an automatic timer system and a gas meter. The gas meter was calibrated before the programme. On the basis of this calibration the accuracy of volume measurements was ± 2 %. The sampling time was about 1.5-2 hours during which at least 1 m^3 but not more than 2 m^3 of air was sampled. The electric current to function the pump was supplied by an electric generator. Exhaust gases from the generator were conducted downwind with a tube. Thus seven aerosol samples were obtained.

The elemental composition was determined by the particle induced X-ray emission (PIXE) method. The details of the analysis are described elsewhere (*Koltay*, 1988). The samples were irradiated by 2 MeV proton beam supplied by the *Van de Graaff* nuclear accelerator of the Nuclear Research Institute of the Hungarian Academy of Sciences, Debrecen, Hungary. Eighteen elements (with atomic number 13 and over) were detected by this procedure: Al, Si, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Br, Ba, Nd and Pb. The detection limits are between 2-100 ng m^{-3} depending on the elements. The blank value for each element was carefully checked. It was found that, except for bromine, blanks could practically be neglected compared to measured concentrations. For this reason concentrations and enrichment factors for bromine were omitted from further examinations. The error of quantitative analysis was lower than 10 % as discussed in more details by *Koltay* (1988).

RESULTS AND DISCUSSION

The absolute concentrations as well as the enrichment factors of 17 elements found in the samples are shown in *Table 2*.

Table 2 Concentration (x: ng m^{-3}) and enrichment factor (EF) of different elements, relative to average crust data, in the atmospheric aerosol over the regions of Indonesia

Ele-	*Sample 1*		*Sample 2*		*Sample 3*		*Sample 4*		*Sample 5*		*Sample 6*		*Sample 6*	
ments	*x*	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*
Al	302	0.54	421	0.46	869	0.53	255	0.58	222	0.80	< 120		< 120	
Si	514	0.27	1415	0.45	2775	0.50	1043	0.69	498	0.53	164	0.43	294	0.52
S	813	458.7	603	204.1	357	68.7	317	223.5	488	550.5	351	990	419	787.9
Cl	5138	5798	105	71.1	277	106.5	756	1066	2932	6615	1396	7874.5	1847	6946.1
K	218	1.2	181	0.61	310	0.6	300	2.1	208	2.4	134	3.8	118	2.2
Ca	654	2.6	974	2.4	1882	2.6	677	3.4	456	3.7	159	3.2	407	5.5
Ti	30	=1	50	=1	88	=1	24	=1	15	=1	6	=1	9	=1
V	11	12	7	4.6	10	3.7	3	4.1	9	19.6	6	32.6	5	18.1
Cr	32	46.9	30	26.4	23	11.5	17	31.2	37	108.5	35	256.7	30	146.7
Mn	17	2.6	21	1.9	36	1.9	15	2.9	7	2.2	< 5		6	3.1
Fe	439	1.3	627	1.1	1093	1.1	279	1.02	157	0.92	65	0.95	97	0.95
Ni	5	9.8	5	5.9	8	5.3	< 3		4	15.6	2	19.6	3	19.6
Cu	28	74.7	20	32	10	9.1	6	20	38	202.6	13	173.3	7	62.2
Zn	11	23.1	48	60.3	30	21.4	14	36.7	4	16.8	< 6		3	21
Ba	46	15.9	14	2.9	16	1.9	7	3	26	17.9	16	27.6	23	26.5
Nd	64	335.3	19	59.7	26	46.4	15	98.2	41	429.5	22	576.2	31	541.3
Pb	< 12		31	209.8	217	834.6	22	310.2	< 12		< 12		< 12	

Considering the absolute concentrations, the concentration of chlorine is found to be at least one order of magnitude higher than that of the other elements in case of the seashore sites. Following chlorine, silicon, sulphur and iron show the highest concentrations. The concentration of silicon is one order of magnitude higher over urban areas (Jakarta, Bandung and Yogyakarta) contrary to seashore sites.

The enrichment of element X relative to average earth crust composition is given by the enrichment factor $EF_{Ti}(X)$ defined as

$$EF_{Ti}(X) = (X/Ti)_{air} / (X/Ti)_{crust} , \quad (1)$$

where Ti is used as a reference crust derived element (*Mason*, 1966), $(X/Ti)_{air}$ is a concentration ratio of an element X to that of Ti in atmospheric particulates and $(X/Ti)_{crust}$ is a concentration ratio of an element X to that of Ti in crust. By using this approach, enrichment factors less than 1 for Al and Si were found at each station, which means that even Ti is partly enriched. The use of titanium as reference element is due to the applied analytical method. At PIXE-analysis the detection limit and the accuracy of the method depend on the atomic number of the given element. The error of determining Al is bigger than that of Ti. Furthermore, Ti has less other (anthropogenic) sources than Al and Fe (see e.g. *Borbély-Kiss et al.*, 1991).

According to the enrichment factors aluminium, silicon, potassium, calcium, manganese and iron are normally taken to be crustal elements, namely their EF at continental sites are below ten, while that of sulphur, chlorine and chromium is well over ten. The enrichment of these elements requires some explanation. Sulphur seems to be enriched everywhere over Indonesia. Generally, most part of S in the air can be found in fine modes of aerosols (size of them is less than 2.5 μm) which are of secondary origin. These aerosols transform to ammonium sulphate drops by chemical processes and can reach remote regions from their sources. In polluted urban areas it is due to oil combustion and industrial thermal processes, while at seashore sulphur comes from other source. Atmospheric sulphates are either emitted directly as primary particles or are products of gas-to-particle conversion which takes place in the atmosphere. Subsequently they can undergo numerous reactions and give rise to a wide variety of sulphates. Sources of S in the atmosphere are well known; oxidation of natural H_2S and $(CH_3)_2S$ results finally in SO_2. On a global scale, the anthropogenic input of SO_2 is also very important. Biological particles can provide an attractive nucleating surface for SO_2 absorption and conversion to sulphates (*Mamame and Noll*, 1985). The absolute concentration of sulphur at sampling site No. 1. is the highest of all sites. This might partly be originated from the Krakatoa volcano settled in the Sunda strait, about 40 km away from the coasts of Western Java. During the period of sampling at site No. 1, the Krakatoa was very active with smoke and ashes following heavy explosions. The EF of chlorine at each site (with the exception of site No. 2.) is well over 100. However, chlorine can be considered of marine origin all over Indonesia, since even typical non-seaside cities are not further from the ocean than 200 km. At sites near to seashore (about 200 km away from the sea) some 80 % of chlorine might be of marine origin (*Cohen et al.*, 1996; *Cohen*, 1998). *Cohen* (1998) received similar result for Jakarta. We did not analyse sodium which, being of marine origin, is also enriched in Jakarta (*Zou and Hooper*, 1997). According *to Cohen et al.* (1996), about 70 % of sodium at seashore sites is of marine origin. The enrichment of chromium in Indonesia shows similarity with that in North-western China. Cr might be partly of industrial origin both in urban sites (Jakarta, Bandung and Yogyakarta) and at seashore. Contrary to this assumption, urban sites show both lowest absolute concentrations and lowest EFs of chromium. Higher concentrations of chromium at seashore sites and its one order of magnitude higher EFs at sampling site No. 5, relative to those at urban sites, can be traced back partly to its soil origin. However, no local samples of soil are at disposal to confirm this hypothesis (*Table 2*).

The rest of the elements (nickel, copper, zinc, barium, neodymium and lead) are mainly of non-crustal ones. According to their enrichment factors, our most important results are that copper, barium and neodymium are enriched at seashores one order of magnitude higher than at urban sites; furthermore, lead is detected and at the same time highly enriched only at urban sites. The cities, where samplings were made, are the most populated (Jakarta: 10 million people; Bandung: 0.5 million people; Yogyakarta: 1 million people) and are full of various types and quality of cars. As an example Jakarta has the second largest traffic in the world (after Bangkok). The high concentration of lead in the cities origins directly from the gasoline of vehicles. Lead compounds can be on the one hand sulphates which are the result of automobile exhausts, on the other hand halides which are emitted by cars and can easily be converted into sulphates by reactions with SO_2 or H_2SO_4 (*Van Malderen et al.*, 1996). In accordance with our results *Zou and Hooper* (1997) found also high concentration of lead and even zinc in Jakarta. Nickel, copper and zinc seem to be enriched all over Indonesia. They are mainly products of non-ferrous metallurgy. Seashores are enriched with them, probably owing to their short distance from industrial centres (*Fig. 1* and *Fig. 2*).

The fraction of elements coming from non-crustal sources [$(c_x)^*$] can be calculated by the following formula (*Mason*, 1966):

$$(c_x)^* = \frac{(c_x)_{air} - (c_{Ti})_{air} \cdot \left(\frac{c_x}{c_{Ti}}\right)_{crust}}{(c_x)_{air}} \text{, where} \qquad (2)$$

$(c_x)_{air}$: is the concentration of an element x in the air
$(c_{Ti})_{air}$: is the concentration of titanium in the air
$(c_x)_{crust}$: is the concentration of an element x in the crust
$(c_{Ti})_{crust}$: is the concentration of titanium in the crust.

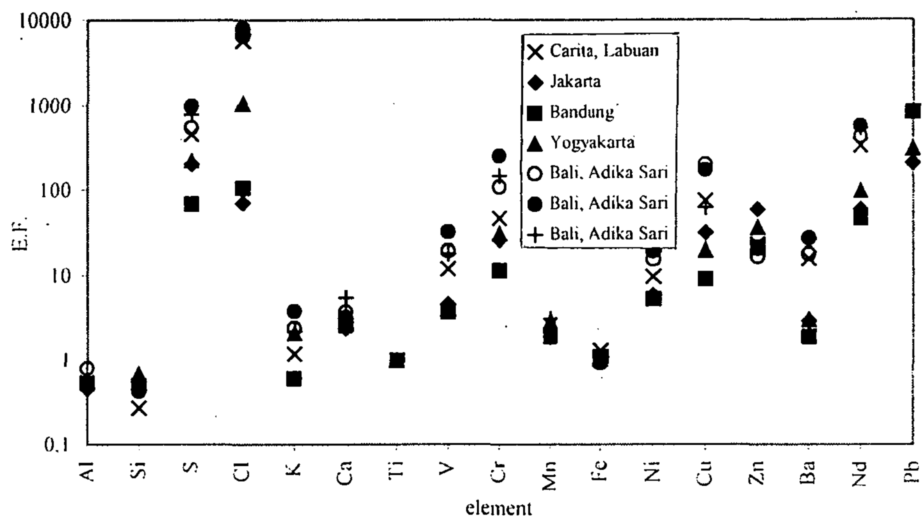

Fig. 2 Enrichment factors of 17 elements at five Indonesian sites

The non-crustal fractions of the detected elements are shown in *Table 3.* According to the results a substantial part of potassium, calcium, manganese and iron comes to the air from the Earth' crust, while aluminium and silicon is entirely of crustal origin. V, Cr, Ni, Cu, Zn, Ba, Nd and Pb are mostly emitted by anthropogenic sources. Chlorine comes basically from the sea, while a substantial part of sulphur originates from anthropogenic sources.

CONCLUSION

Absolute concentrations of chlorine are higher than those of sulphur only at seashore sites. S and Cl are highly enriched at each sampling sites. Most part of chlorine is supposed to come from sea spray, while a substantial part of sulphur presumably comes also from natural source, from biogenic emission of the sea. Chromium is highly enriched at seashore sites, much higher than at urban sites. This shows similar result to high chromium concentrations in the Takla Makan Desert (*Molnár et al.*, 1993a; *Makra et al.*, 1999), which confirms our hypothesis of its soil origin. Cu, Zn, Ba and Nd are highly enriched at each site, while Pb is only enriched at urban sites. They all can mostly be attributed to anthropogenic sources.

Table 3 Non-crustal fractions of aerosol particles, relative to average crust data, %

Ele-ments	Sample No.						
	1	*2*	*3*	*4*	*5a*	*5b*	*5c*
Al	0	0	0	0	0	0	0
Si	0	0	0	0	0	0	0
S	100	100	99	100	100	100	100
Cl	100	99	99	100	100	100	100
K	17	0	0	52	58	74	55
Ca	62	58	62	71	73	69	82
Ti	0	0	0	0	0	0	0
V	92	78	73	76	95	97	94
Cr	98	96	91	97	99	100	99
Mn	62	47	47	66	55		68
Fe	23	9	9	2	0	0	0
Ni	90	83	81		94	95	95
Cu	99	97	89	95	100	99	98
Zn	96	98	95	97	94		95
Ba	94	66	47	67	94	96	96
Nd	100	98	98	99	100	100	100
Pb		100	100	100			

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REFERENCES

Adams, F., Van Craen, M., Van Espen, P. and Andreuzzi, D., 1980: The elemental composition of atmospheric aerosol particles at Chacaltaya, Bolivia. *Atmos. Environ. 14*, 879-893.

Adams, F., Van Espen, P. and Maenhaut, W., 1983: Aerosol composition of Chacaltaya, Bolivia, as determined by size-fractionated sampling. *Atmos. Environ. 17*, 1521-1536.

Borbély-Kiss, I., Bozó, L., Koltay, E., Mészáros, E., Molnár, A. and Szabó, Gy., 1991: Elemental composition of aerosol particles under background conditions in Hungary. *Atmos. Environ. 25A*, 661-668.

Borbély-Kiss, I., Koltay, E., Szabó, Gy., Bozó, L., and Tar, K., 1999: Composition and sources of urban and rural atmospheric aerosol in Eastern Hungary. *J. Aerosol Sci.* **30**, 369-391.

Cohen, D.D., Bailey, G.M., and Kondepudi, R., 1996: Elemental analysis by PIXE and other IBA techniques and their application to source fingerprinting of atmospheric fine particle pollution. *Nucl. Instrum. and Meth. in Phys. Res. B109-110*, 218-226.

Cohen, D.D. 1998: Characterisation of atmospheric fine particles using IBA techniques. *Nucl. Instrum. and Meth. in Phys. Res. B136-138*, 14-22.

Fan, X.B., Okada, K., Niimura, N., Kai, K., Arao, K., Shi, G.Y., Qin, Y. and Mitsuta Y., 1996: Mineral particles collected in China and Japan during the same Asian dust storm event. *Atmos. Environ. 30*, 347-351.

Hashimoto, Y., Sekine, Y., Kim, H.K., Chen, Z.L. and Yang, Z.M., 1994: Atmospheric fingerprints of East Asia, 1986-1991. An urgent record of aerosol analysis by the Jack Network. *Atmos. Environ. 28*, 1437-1445.

Hu, Z.H., Zhong, M., Liu, Q.X., Zhong, H.H., Jiang, J.L. and Hu G.H., 1987: PIXE analysis of aerosols from the southern city Guangzhou. *Nucl. Instrum. and Meth. in Phys. Res. B22*, 283-288.

Koltay, E., 1988: Particle induced X-ray emission: basic principles, instrumentation and interdisciplinary applications. In *X-ray Spectroscopy in Atomic and Solid State Physics* (edited by *Ferreira, J.G. and Ramos, M.T.*). NATO Advanced Study Institute Series. Series B, Plenum Press, New York, 301-334.

Koltay, E., 1990: Elemental analysis of atmospheric aerosols: Results and perspectives of the PIXE technique. *International Journal of PIXE 1*, 93-112.

Landsberg, H.E. ed. in chief, 1969: *World Survey of Climatology.* Elsevier Publishing Company. Amsterdam - London - New York. Vol. 8.

Maenhaut, W. and Malmqvist, K.G. 1992: Particle-induced X-ray emission analysis. In: *Handbook on X-ray spectrometry: Methods and techniques* (edited by Van Grieken, R. and Markowicz, A.A.), Marcel Dekker Inc., New York, 517-581.

Makra, L., Borbély-Kiss, I., Koltay, E. and Chen, Y., 1999: PIXE analysis of atmospheric aerosol particles in North-western China. *Acta Clim. Univ. Szegediensis 32-33, (This issue)*, 77-100.

Mamane, Y. and Noll, K.E., 1985: Characterization of large particles at a rural site in the eastern United States: Mass distribution and individual particle analysis. *Atmos. Environ. 19*, 611-622.

Mason, B., 1966: *Principles of Geochemistry*. Wiley, New York.

Mészáros, E., 1978: Concentration of sulphur compounds in remote continental and oceanic areas. *Atmos. Environ. 12*, 699-705.

Molnár Á., Makra, L., Chen, Y. and Borbély-Kiss, I., 1993a: Some data on the elemental composition of atmopsheric aerosol particles in Xinjiang, NW China. *Időjárás 97*, 173-177.

Molnár, Á., Mészáros, E., Bozó, L., Borbély-Kiss, I., Koltay, E. and Szabó, Gy., 1993b: Elemental composition of atmospheric aerosol particles under different conditions in Hungary. *Atmos. Environ. 27A*, 2457-2461.

Molnár, Á., Mészáros, E., Polyák, K., Borbély-Kiss, I., Koltay, E. and Szabó, Gy., 1995: Atmospheric budget of different elements in aerosol particles over Hungary. *Atmos. Environ. 29*, 1821-1828.

Morales, J.A., Hermoso, M., Serrano, J. and Sanhueza, E., 1990: Trace elements in the Venezuelan savannah atmosphere during dry and wet periods, with and without vegetation burning. *Atmos. Environ. 24A*, 407-414.

Ning, D.T., Liang, X.Z. and Chung, Y.S., 1996: Aerosol size distribution and elemental composition in urban areas of Northern China. *Atmos. Environ. 30*, 2355-2362.

Penkett, S.A., Atkins, D.H.F. and Unsworth, M.H., 1979: Chemical composition of the ambient aerosol in the Sudan Gezira. *Tellus 31*, 295-307.

Van Malderen, H., Van Grieken, R., Khodzher, T., Obolkin, V. and Potemkin, V., 1996: Composition of individual aerosol particles above Lake Baikal, Siberia. *Atmos. Environ. 30*, 1453-1465.

Winchester, J.W., Lü, W.X., Ren, L.X., Wang, M.X. and Maenhaut, W., 1981a: Fine and coarse aerosol composition from a rural area in North China. *Atmos. Environ. 15*, 933-937.

Winchester, J.W., Wang, M.X., Ren, L.X., Lü, W.X., Hansson, H.C., Lannefors, H., Darzi. M. and Leslie, C.D.A., 1981b: Nonurban aerosol composition near Beijing, *China. Nucl. Instrum. and Meth. 181*, 391-398.

Winchester, J.W. and Wang, M.X., 1989: Acid-base balance in aerosol components of the Asia-Pacific region. *Tellus 41B*, 323-337.

Zhang, X.Y., Arimoto, R., An, Z.S., Chen, T., Zhang, G.Y., Zhu, G.H. and Wang, X.F., 1993: Atmospheric trace elements over source regions for Chinese dust: concentrations, sources and atmospheric deposition on the Loess Plateau. *Atmos. Environ. 27A*, 2051-2067.

Zou, L.Y. and Hooper, M.A., 1997: Size-resolved airborne particles and their morphology in Central Djakarta. *Atmos. Environ. 31*, 1167-1172.

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PIXE ANALYSIS OF ATMOSPHERIC AEROSOL PARTICLES IN NORTH-WESTERN CHINA

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Összefoglalás - Makra László második kínai terepi mûszeres expedíciója során, 1994-ben 21 db aeroszol mintát gyûjtött Északnyugat-Kína arid és rendkívül ritkán lakott térségeiben. A mintákat PIXE-módszerrel analizáltuk. A tanulmány legfontosabb eredménye annak kimutatása, hogy a kén, a klór, a króm, a réz és a cink szignifikánsan földúsul az Északnyugat-Kína fölötti légköri aeroszolban. Bebizonyítottuk, hogy a kén és a klór talaj eredetû. A króm, a réz és a cink koncentrációi nem ismeretesek a helyi talajban. Mégis valószínûsítjük, hogy földúsulásuk a légköri aeroszolban, anomalikusan magas talajkoncentrációjukra vezethetõ vissza. A kén és a klór eredete Északnyugat-Kínában eltérõ a Föld egyéb, hasonlóan száraz és gyéren lakott régióihoz képest.

Summary - Twenty-one aerosol samples were collected by László Makra in the air over arid regions of North-western China during a Hungarian expedition in 1994. the The samples collected were analysed by PIE-method. The most important result of the study is, revealing highly enriched sulphur, chlorine, chromium, copper and zinc in the atmospheric aerosol over North-western China. It is clearly proved that sulphur and chlorine come from local soil. Concentration data of chromium, copper and zinc in local soil of North-western China are not available. However it is supposed that these elements come from local soil, as well. The origin of sulphur and chlorine here shows a difference from that of other similar lands of the Earth.

Key words: elemental composition, enrichment factor, non-crustal fraction, China, Inner Asia

INTRODUCTION

North-western China is the innermost part of Eurasia, which covers a vast expanse, accounting for more than 20 per cent of the total area of China. It is bordered by the Altay Mountains from North, by the Kunlun Mountains from South, by the Pamir from West and by the Altin Mountains from East. North-western China has a strong continental climate with scarce precipitation and a great variation in its range of temperature. It is situated in middle-latitude westerlies, where both high and low pressures are active. The region is under the Mongolian high for most of the winter half-year. During this period the region is frequently invaded by the polar and arctic air masses. Influenced by strong radiation cooling of the ground surface, the climate in the winter is mainly dry and cold. In summer, as the region is located at the northern fringe of the continental low, the strong westerlies convey vapour quickly. Most of the exposed ground surface is then heated to extremely high temperatures. Due to the dynamical and thermodynamical influence of the air currents from the Qinghai-Tibetan Plateau, a high altitude tropical continental air mass forms over the Tarim Basin.

Deserts with gravel or sand cover vast areas. The largest one is the Takla Makan while the second largest desert is the Gurbantunggut which is found in the Junggar Basin.

The climate here is dry with little cloud cover and abundant sunshine. This is the most arid region in China, with aridity over 4. In the Tarim Basin the annual precipitation is only about 50 mm and the aridity is over 10 (*Domroes and Peng*, 1988). [The aridity is a quotient of the radiation balance and the precipitation amount for a given region and period. This quotient is in direct proportion to the dryness of climate and inversely proportional to the water supply. If the aridity is higher than 1, the climate is arid (the radiation balance would make it possible to evaporate more water than that, which is at disposal), while if it is below 1, the climate is humid (the precipitation amount is higher than the potential evaporation). Aridity over 4 represents extremely dry regions.]

The vegetation on the ground surface is sparse, the air is dry and dry winds blow frequently. Dry winds generally occur between April and August and often blow at a velocity exceeding 10 m s^{-1} from late May to late June. The plants generally do not cover more than 20 per cent of the ground surface and sometimes as little as 1 per cent, e.g. the southern slopes of the Tianshan Mountains. Even there are large areas of gravel and shifting dunes void of any vegetation mainly in the extremely arid Takla Makan Desert and the Qaidam Basin. 85 per cent of the Takla Makan is shifting by winds. This is the largest shifting sand desert in the world.

Soils in this region are grey-brown desert soil under the arid climate and aeolian sandy soil under the extremely arid climate. Under the influence of climate and vegetation the top of these desert soils contains little organic matter and there is no humus accumulation. It contains calcium carbonate in the upper layer and gypsum even in lower layers, too. There is a certain amount of salt in the soil, mostly sodium sulphate and sodium chloride. Because of the extreme aridity, the soil in the Tarim Basin also contains salt pans of chlorides, which are rarely found in desert soil in other parts of the world. The whole profile produces a medium or strong alkaline reaction (pH 8.0 to 10.0) (*Ren and Bao*, 1985).

The Junggar Basin is found north from the Tianshan Mountains and south from the Altay Mountains. It receives slightly more precipitation than the Tarim Basin. Consequently its margins are steppes and only its interior is desert.

The northern slopes of the Tianshan Mountains face to humid north-west current and receive much more precipitation than do the slopes at the same elevation in the Kunlun Mountains. The Tarim Basin south of the Tianshan Mountains is far drier than the Junggar Basin, and therefore the desert penetrates deep into the mountains here.

The characteristics of the southern fringe of the Tarim Basin (the northern slopes of the Kunlun Mountains) are the extreme aridity. E.g. in the middle section of the Kunlun Mountains desert vegetation with mountain brown desert soil can be found up to 3500 m above sea level.

The soil at the northern slopes of the Tianshan Mountains is grey-cinnamon forest soil, which produces a neutral to alkaline reaction with a pH value of between 7.0 and 8.0. The soil not only reflects some typical features in the formation of cinnamon soil (clayization and carbon accumulation) but also some in the formation of the grey forest soil (humus accumulation).

Most areas in North-western China are closed inland basins without outlets for the runoff and salts. Because the climate is dry and there is strong evaporation, a heavy accumulation of salts has formed in the basins over a long time. Solonchak is widespread and the salt content in this is very high. (Solonchak is a soil type, which is rich in soda. Its soil structure is homogenous. Its upper layer is the saltiest and on its surface there is salt efflorescence from place to place and time to time.) The surface layer of the solonchak contains 2-5 per cent salts, while the solonchak in southern Xinjiang (this is the Chinese name of the province of North-western China) and the Qaidam Basin contains from 10-20 per cent. Most of the solonchak in North-western China contains chlorides, sulphates or soda (*Ren and Bao*, 1985).

This region is very rich in mineral resources although geologic mapping has not been completed. Rich supplies of coal, iron and ores can be found, however oil is the most important. The exploitaton of oil started in 1977 and by now North-western China has become the second region for oil production in China. Nevertheless, oil reserves in the Tarim Basin are as much as 12 billion tons, which are the largest ones in China and three times as much as those of the United States. The length of local rails is a mere 400 km and only parts of the highways are covered. Long-distance transportation is performed by lorries but local traffic, predominantly in the oases of the Tarim Basin, occurs by two-wheeled tumbrils drawn by donkeys. Local industry is developing faster in the last decade. Contrary to the present economic development, North-western China is far from major pollution sources and can be considered as a background region.

The elemental composition of atmospheric aerosol particles has been studied widely during the last three decades. Aerosols play an important role in the atmosphere, e.g. by modifying radiation transfer, cloud, fog and precipitation formations; even they influence human health. The reason of such measurements is estimating the environmental impact of the particles on local, regional and global scales. Among other things, samplings in the atmosphere far from human activities have been carried out under oceanic and continental conditions to investigate the global cycle of aerosols. In spite of these efforts (e.g. *Mészáros*, 1978; *Penkett et al.*, 1979; *Adams et al.*, 1980, 1983; *Winchester et al.*, 1981a, 1981b; *Morales et al.*, 1990;), the chemical composition of aerosol particles far from anthropogenic pollution sources over continents like Africa, South America and Asia is not well understood.

Although several papers have been published on the air pollution characteristics of urban and other inhabited regions of China (e.g. *Hu et al.*, 1987; *Ge et al.*, 1989; *Hashimoto et al.*, 1994; *Zelenka et al.*, 1994; *Fan et al.*, 1996; *Ning et al.*, 1996) nevertheless few information have been available from the aerosol in the air over Indonesia (e.g. *Zou and Hooper*, 1997) and in that over the vast regions of Asia. Elemental composition of atmospheric aerosols was analysed e.g. over Lake Baikal region (*Van Malderen et al.*, 1996); over Northern China (*Winchester et al.*, 1981a, 1981b; *Fan et al.*, 1996); in the Huangshan Mountain, Eastern China (*Xu et al.*, 1991); and on the Loess Plateau (*Zhang et al.*, 1993). However, relatively few papers have been published in the subject over the huge innermost regions of Asia, and North-western China (*Wang et al.*, 1987; *Winchester and Wang*, 1989; *Molnár et al.*, 1993b; *Hashimoto et al.*, 1994).

One of the frequently applied techniques of elemental analytics of atmospheric aerosols is the PIXE method. Possibilities of this procedure are discussed, among other papers, in comprehensive studies of *Koltay* (1990), furthermore *Maenhaut and Malmqvist* (1992). Authors of the present manuscript applied this technique, among other papers, in *Borbély-Kiss et al.* (1991, 1999), *Molnár et al.* (1993a, 1995) for qualification of regional aerosols. Technical details are given in these papers.

The aim of this paper is to present the results of aerosol samples collected in the air over North-western China (Xinjiang Province).

SAMPLING AND ANALYSIS

The geographical position and characteristics of the sampling sites are given in *Fig. 1-2* and *Table 1* (Samplings at sites No. 3., 19. and 21. were performed both in 1990 and 1994. These sites were written by bold letters.) All the sites are characteristic for regional background conditions. This means that they are not influenced directly by local pollution sources.

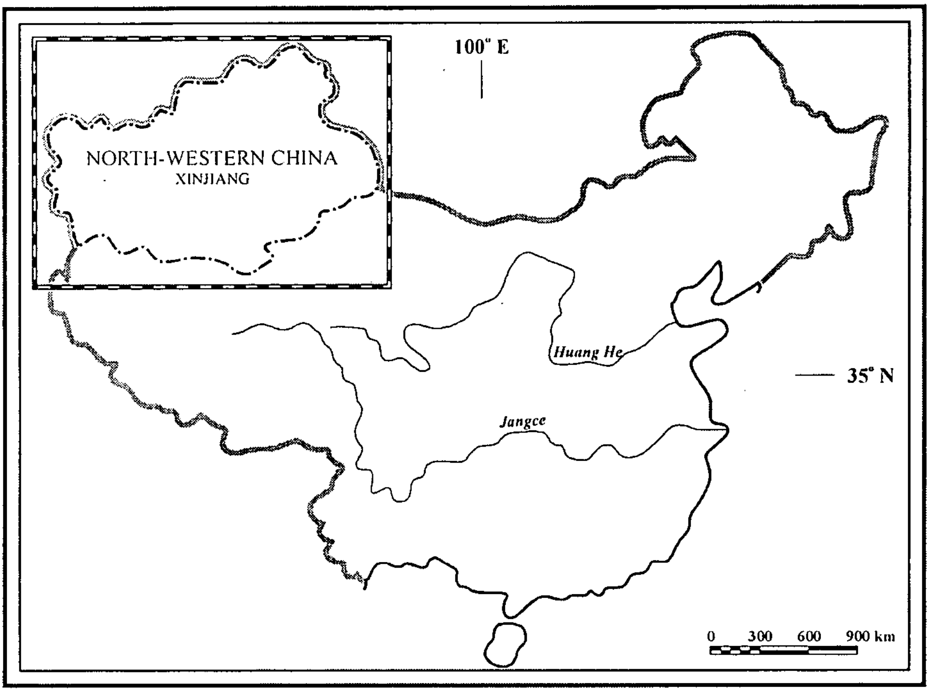


Fig. 1 Map of China with the position of North-western China

Atmospheric aerosol particles were collected in each case by means of Nuclepore polycarbonate filters with pore size of 0.4 μm. The sampling was performed at 1.5 m height. The filter holder was connected to a vacuum pump, which was operated at a flow rate of approximately 20 l min^{-1}. The pump was equipped with an automatic timer system and a gas meter. The gas meter was calibrated before the programme. On the basis of this calibration, the accuracy of volume measurements was ±2 %. The sampling time was about 1.5-2 hours during which at least 1 m^3 but not more than 2 m^3 of air was sampled. The electric current to function the pump was supplied by an electric generator. The exhaust gases from the generator were conducted downwind with a tube. Thus, twenty-one aerosol samples were obtained in North-western China and seven samples in Indonesia. After samplings, the filters of 15 mm diameter were placed into small plexiglas boxes sealed carefully. The filters were kept in these boxes until their analysis in Hungary.

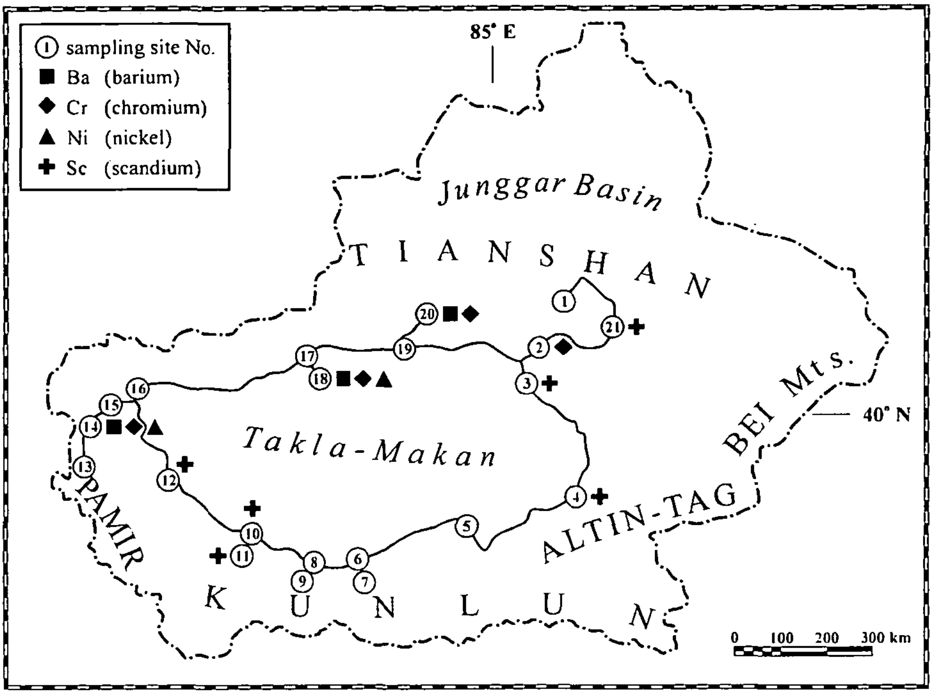


Fig. 2 Position of sampling sites in North-western China with spatial distribution of elements enriched over ten, excluding sulphur, chlorine, copper and zinc

The elemental composition was determined by particle induced X-ray emission (PIXE) method. The details of the procedure applied are described elsewhere (*Koltay*, 1988). Briefly, the samples were irradiated by 2 MeV proton beam supplied by the Van de Graaff nuclear accelerator of the Nuclear Research Institute of the Hungarian Academy of Sciences, Debrecen, Hungary. Nineteen elements (with atomic number 13 and over) were detected by this procedure: Al, Si, S, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Br and Ba. The detection limits are between 2-100 ng m^{-3} depending on the elements. The blank value for each element was carefully checked. It was found that, except for bromine, blanks could practically be neglected compared to measured concentrations. For this reason concentrations and enrichment factors for bromine were omitted from further examinations. The error of quantitative analysis was lower than 10 % as discussed in more details by *Koltay* (1988).

Table 1 Date of sampling; geographical positions and description of sampling sites, North-western China

Sample No.	*Date*	*H (m)*	*φ (°N)*	*λ (°E)*	*Site description*
1	12 June	3370	43° 10'	86° 55'	Glacier No.1. of Tianshan (mountain)
2	16 June	1048	41° 55'	86° 46'	Bosten-Lake
3	17 June	885	41° 23'	86° 22'	**Yuli, Takla Makan (desert)**
4	18 June	860	39° 05'	88° 15'	Ruoqiang, Takla Makan (desert)
5	19 June	1240	38° 07'	85° 35'	Qiemo, Takla Makan (desert)
6	21 June	1410	37° 02'	82° 50'	Minfeng, Takla Makan (desert)
7	22 June	2150	36° 39'	83° 05'	Aryidake, Kunlun (mountain desert)
8	23 June	1390	36° 49'	81° 40'	Yutian, Takla Makan (desert)
9	24 June	1720	36° 40'	81° 19'	Tulake, Takla Makan (desert)
10	25 June	1420	37° 07'	79° 59'	Hotan, Takla Makan (desert)
11	26 June	2150	36° 57'	79° 55'	Yurungkash River, Takla Makan (desert)
12	27 June	1315	37° 55'	77° 47'	Yarkant, Takla Makan (desert)
13	30 June	3010	37° 51'	75° 07'	Tashkurgan, Pamir (mountain)
14	01 July	3595	38° 29'	75° 02'	Kara Kul Lake, Pamir, (mountain)
15	02 July	1900	39° 02'	75° 47'	Mayaz, Pamir (mountain desert)
16	03 July	1410	39° 37'	75° 39'	Kashgar, Takla Makan (desert)
17	04 July	1180	41° 16'	80° 19'	Aksu, Takla Makan (desert)
18	05 July	1085	40° 39'	80° 47'	Arlere Eku, Takla Makan (desert)
19	07 July	1400	41° 55'	82°57'	**Du-ku, Tianshan (mountain)**
20	09 July	2420	42° 22'	83°14'	Dalong Chi, Tianshan (mountain)
21	10 July	0	42° 39'	88° 47'	**Toksun, Turpani Basin (lowland, desert)**

RESULTS AND DISCUSSION

The results of the analyses of samples are in *Table 2a-c*, where the absolute concentrations as well as the enrichment factors of 16 elements are shown. The enrichment of element X relative to average earth crust composition is given by the enrichment factor $(EF)_{Ti}(X)$ defined as

$$EF_{Ti}(X) = (X/Ti)_{air} / (X/Ti)_{crust} \quad (1)$$

where Ti is used as a reference crust derived element (*Mason*, 1966), while $(X/Ti)_{air}$ is a concentration ratio of an element X to that of Ti in atmospheric particulates and $(X/Ti)_{crust}$ is a concentration ratio of an element X to that of Ti in crust. The use of titanium as reference element is due to the applied analytical method. At PIXE-analysis, the detection limit and the accuracy of the method depend on the atomic number of the given element. The error of determining Al is bigger than that of Ti. Furthermore, Ti has less other (anthropogenic) sources than Al and Fe (e.g. *Borbély-Kiss et al.*, 1991).

We can see from the *Table 2a-c.* that relatively high concentrations were found for aluminum, silicon, sulfur, chlorine, potassium, calcium and iron at each sampling site. Aluminum, silicon, potassium, calcium, vanadium, manganese and iron have enrichment factors near to 1 proving their crustal origin. The concentration of the elements of soil origin is extremely high in particular for the samples No. 4, 10, 11 and 12. All these samples were collected at the southern part of the Takla Makan Desert, several days after dust storms. In the Tarim Basin, predominantly occupied by the Takla Makan Desert, winds are frequent and violent in the summer half-year. Following dust storms, dust particles get deposited in several days, while visibility is very weak and it seems as if there were fog around.

Table 2a Concentration (x: ng m^{-3}) and enrichment factor (EF) of different elements relative to average crust data, in the atmospheric aerosol over the regions of North-western China

	Sample 1		*Sample 2*		*Sample 3*		*Sample 4*		*Sample 5*		*Sample 6*		*Sample 7*	
	x	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*
Al	337	0.44	482	0.67	3217	0.48	6925	0.50	4349	0.33	2642	0.48	1295	0.60
Si	2176	0.84	2281	0.93	17140	0.75	34320	0.73	21000	0.48	13790	0.74	5506	0.75
S	516	212.9	439	190.5	1122	52.2	4034	91.5	2248	54.5	1544	87.9	485	70.7
Cl	108	89.1	71	61.6	1034	96.2	5056	229.5	2038	98.8	1500	170.8	465	135.6
K	346	1.4	384	1.7	2727	1.3	5374	1.2	3532	0.86	2276	1.3	849	1.2
Ca	1020	3	1044	3.2	11850	4	28690	4.7	13970	2.4	8350	3.4	3538	3.7
Sc	<20		<20		20	11	73	19.6	<20		<20		<20	
Ti	41	=1	39	=1	364	=1	745	=1	703	=1	298	=1	116	=1
V	4	3.2	6	5	14	1.3	<3		<3		15	1.6	5	1.4
Cr	5	5.4	9	10.2	39	4.7	53	3.1	75	4.7	32	4.7	8	3
Mn	17	1.9	19	2.3	107	1.4	189	1.2	106	0.70	81	1.3	40	1.6
Fe	605	1.3	563	1.3	4356	1.1	9576	1.1	5707	0.72	3542	1.05	1393	1.1
Ni	<3		4	6	17	2.7	49	3.9	67	5.6	26	5.1		
Cu	125	243.9	45	92.3	245	53.9	624	66.9	374	42.8	226	60.8	81	55.8
Zn	51	78.2	20	32.2	166	28.7	300	25.3	266	23.9	131	27.7	48	26
Ba	<15		16	4.2	43	1.2	<15		<15		<15		<15	

Table 2b Concentration (x: ng m^{-3}) and enrichment factor (EF) of different elements relative to average crust data, in the atmospheric aerosol over the regions of North-western China

	Sample 1		*Sample 2*		*Sample 3*		*Sample 4*		*Sample 5*		*Sample 6*		*Sample 7*	
	x	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*
Al	3368	0.53	2016	0.50	13420	0.43	5168	0.55	28520	0.35	1674	0.60	324	0.76
Si	16350	0.75	10730	0.77	74160	0.70	23350	0.72	171300	0.61	7076	0.74	1170	0.81
S	1065	52.4	900	69.2	4021	40.2	2883	95.4	6966	26.8	624	69.8	280	206
Cl	939	92.5	856	131.7	8023	160.5	4820	318.9	4526	34.8	203	45.4	48	70.6
K	2489	1.2	1542	1.2	11510	1.2	3820	1.3	26610	1.03	1147	1.3	193	1.4
Ca	8937	3.2	6485	3.6	44250	3.2	15480	6	118200	3.3	4405	3.5	529	2.8
Sc	<20		<20		230	27.2	38	14.9	699	31.8	<20		<20	
Ti	345	=1	220	=1	1680	=1	509	=1	4427	=1	151	=1	23	=1
V	21	2	10	1.5	38	0.73	10	0.64	152	1.1	9	1.9	3	4.3
Cr	52	6.7	26	5.2	353	9.2	52	4.5	492	4.9	11	3.2	8	15.3
Mn	99	1.3	59	1.2	310	0.85	136	1.2	718	0.76	59	1.8	10	2
Fe	4332	1.1	2676	1.1	18500	0.96	6497	1.1	49700	0.99	1905	1.1	333	1.3
Ni	41	7	21	5.6	<3		29	3.3	<3		<3		4	10.2
Cu	255	59.3	166	60.4	1291	6.1	471	73.6	<3		12	6.3	6	20.9
Zn	141	25.8	84	24	407	15.1	198	24.3	1596	22.8	114	47.4	16	43.7
Ba	87	2.6	<15		<15		<15		584	3.9	52	3.6	28	12.6

Table 2c Concentration (x: ng m^{-3}) and enrichment factor (EF) of different elements relative to average crust data, in the atmospheric aerosol over the regions of North-western China

	Sample 1		*Sample 2*		*Sample 3*		*Sample 4*		*Sample 5*		*Sample 6*		*Sample 7*	
	x	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*	*x*	*EF*
Al	1728	0.66	3330	0.46	1443	0.67	96	0.58	1010	0.51	354	0.71	4604	0.49
Si	6968	0.78	19690	0.80	5605	0.76	831	1.5	4348	0.64	1428	0.84	21730	0.67
S	757	90.8	1567	67.5	456	65.9	290	545.3	378	59.8	381	238.9	1261	41.7
Cl	298	71.5	433	37.3	180	52.1	164	616.8	406	128.4	42	52.7	873	57.8
K	1143	1.4	3117	1.3	1074	1.6	193	3.6	851	1.4	219	1.4	3850	1.3
Ca	3753	3.2	13300	4.1	3697	3.8	665	9	2166	2.5	507	2.3	11700	2.8
Sc	<20		<20		<20		<20		<20		<20		33	12.9
Ti	141	=1	393	=1	117	=1	9	=1	107	=1	27	=1	511	=1
V	9	2.1	16	1.3	7	1.9	3	10.9	7	2.1	3	3.6	17	1.1
Cr	10	3.1	41	4.6	12	4.5	9	44	8	3.3	10	16.3	23	2
Mn	51	1.7	115	1.4	56	2.2	12	6.2	32	1.4	13	2.2	123	1.1
Fe	1780	1.1	4886	1.1	1553	1.2	231	2.3	1263	1.04	366	1.2	6333	1.1
Ni	<3		26	3.9	<3		4	26.1	<3		3	6.5	<3	
Cu	45	25.5	187	38.1	62	42.4	28	248.9	209	156.2	38	112.6	<3	
Zn	70	31.2	203	32.5	67	36	14	97.8	92	54	13	30.3	<6	
Ba	51	3.7	<15		30	2.7	23	26.4	40	7.6	42	16.1	<15	

Sulphur and chlorine are enriched considerably at all sites. Enrichment factors of chlorine at sampling sites in the Takla Makan Desert are higher than those of sulphur; however, those for both are generally between 100 and 500. These elements are enriched presumably as a result of the disintegration of the surface. In more detail, it is proposed considering with caution the idea of the highly enriched sulphur and chlorine content of the air over North-western China, as follows. Because of the extreme aridity, soils in the Tarim Basin contain largely a certain amount of salt, mostly sodium sulphate and sodium chloride. Besides several lakes contain a lot of sodium chloride in the regions considered. Soils here largely contain gypsum not only in their upper layer but in their lower ones, as well. This is a particulate matter that contains both Ca and S ($CaSO_4 \cdot 2H_2O$). In deserts and semi-deserts [also at fringes of the mountains (Tianshan Mountains, Pamir, Kunlun Mountains) surrounding the Tarim Basin], gypsum frequently occurs as a result of the weathering of rocks of different composition. High enrichment factors of sulfur and chlorine at sampling sites at high mountains (sample numbers 1, 13 and 14) can be explained on the one hand by the composition of local soil different of that of average earth crust, and on the other hand by particulates transported by air currents from the arid regions of Inner Asia.

The above mentioned potential soil origin of S and Cl was investigated by using elemental concentrations of samples of local soil, which was collected in the Takla Makan Desert (*Suzuki et al.*, 1993). It was found that concentrations for sulfur and chlorine in samples of soil were at some cases by two orders of magnitude higher than those in the average crust (*Mason*, 1966) (*Table 3*).

From the equation (1) the connection between $EF_{Fe,\,soil}(x)^1$ (enrichment factor of an element x to that of Fe relative to soil) and $EF_{Fe,\,crust}(x)^2$ (enrichment factor of an element x to that of Fe relative to crust) is as follows:

$$EF_{Fe,\,soil}(x)^1 = [(x/Fe)_{crust}^{\;2} \,/\, (x/Fe)_{soil}^{\;1}] \cdot EF_{Fe,crust}(x)^2 \quad (2)$$

[1] *Suzuki et al.* (1993)
[2] *Mason* (1966)

The quotient at the right hand side of the equation (2) is well below 1 (see *Table 3*). Consequently, enrichment factors (EFs) calculated relative to soil decrease considerably (*Table 4a, 5a*). In most cases, values of $EF_{Fe,soil}(S)$ and $EF_{Fe,\,soil}(Cl)$ are near (sometimes even below) 1, which clearly indicate the soil origin of sulfur and chlorine in the Takla Makan Desert (*Table 4a*). According to this result, enrichment factors of S and Cl in the Tarim Basin are proposed to be determined by not relative to the average crustal data (*Mason*, 1966) but by relative to the local soil (*Suzuki et al.*, 1993).

Table 3 Elemental ratios of average crust[1] relative to those of local soil[2], North-western China

Sampling region*	$\frac{(c_S/c_{Fe})_{crust^1}}{(c_S/c_{Fe})_{soil^2}}$	$\frac{(c_{Cl}/c_{Fe})_{crust^1}}{(c_{Cl}/c_{Fe})_{soil^2}}$	$\frac{(c_{Cu}/c_{Fe})_{crust^1}}{(c_{Cu}/c_{Fe})_{soil^2}}$	$\frac{(c_{Zn}/c_{Fe})_{crust^1}}{(c_{Zn}/c_{Fe})_{soil^2}}$	$\frac{(c_K/c_{Fe})_{crust^1}}{(c_K/c_{Fe})_{soil^2}}$	$\frac{(c_{Ca}/c_{Fe})_{crust^1}}{(c_{Ca}/c_{Fe})_{soil^2}}$	$\frac{(c_{Mn}/c_{Fe})_{crust^1}}{(c_{Mn}/c_{Fe})_{soil^2}}$
A	0.0141	0.0032	0.7333	0.6364	1.5463	0.9052	0.8261
B	0.2167	0.1182	1.8333	0.7778	0.7945	0.7311	0.8636
C	0.1486	0.0394	0.1158	0.6364	0.6852	0.3903	0.7037
D	0.1793	0.0356	0.8462	0.6667	0.6710	0.3227	0.7917

[1] *Mason* (1966)

[2] *Suzuki et al.* (1993)

* A and B sampling regions are found at the North-eastern part, while C and D at the south-western part of the Takla Makan Desert (*Suzuki et al.*, 1993)

Table 4a Enrichment factors of S, Cl, Cu and Zn relative to local samples of soil[1], North-western China

Element*	Sample No.																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
S_A	2.31	2.11	0.70	1.14	1.06	1.18	0.94	0.66	0.91	0.59	1.20	0.38	0.89	2.28	1.15	0.87	0.80	3.39	0.81	2.81	0.54
S_B	35.54	32.49	10.73	17.55	16.41	18.16	14.51	10.24	14.01	9.06	18.49	5.84	13.65	35.04	17.72	13.36	12.23	52.31	12.47	43.37	8.30
S_C	24.37	22.28	7.36	12.04	11.25	12.45	9.95	7.02	9.61	6.21	12.68	4.00	9.36	24.02	12.15	9.16	8.39	35.87	8.55	29.74	5.69
S_D	29.41	26.89	8.88	14.53	13.58	15.03	12.01	8.48	11.60	7.49	15.30	4.83	11.30	28.99	14.66	11.06	10.13	43.29	10.32	35.90	6.87
Cl_A	0.22	0.16	0.29	0.65	0.44	0.52	0.41	0.27	0.39	0.54	0.92	0.11	0.13	0.18	0.21	0.11	0.14	0.88	0.40	0.14	0.17
Cl_B	8.11	5.73	10.79	24.00	16.23	19.25	15.17	9.85	14.54	19.71	6.27	4.14	4.84	6.55	7.61	4.03	5.27	32.27	14.61	5.22	6.27
Cl_C	2.70	1.91	3.60	8.00	5.41	6.42	5.06	3.28	4.85	6.57	11.24	1.38	1.61	2.18	2.54	1.34	1.76	10.76	4.87	1.74	2.09
Cl_D	2.45	1.73	3.25	7.23	4.89	5.80	4.57	2.97	4.38	5.94	10.16	1.25	1.46	1.97	2.29	1.21	1.59	9.73	4.40	1.57	1.89
Cu_A	137.7	53.29	37.50	43.44	43.69	42.50	38.77	39.24	41.36	46.52	48.33	-	4.20	12.01	16.85	25.52	26.62	80.80	110.3	69.22	-
Cu_B	344.4	133.2	93.74	108.6	109.2	106.3	96.91	98.11	103.4	116.3	120.8	-	10.50	30.03	42.13	63.79	66.54	202.0	275.8	173.0	-
Cu_C	21.75	8.41	5.92	6.86	6.90	6.72	6.12	6.20	6.53	7.35	7.63	-	0.66	1.90	2.66	4.03	4.20	12.76	17.42	10.93	-
Cu_D	158.9	61.48	43.26	50.13	50.41	49.08	44.73	45.28	47.72	53.68	55.77	-	4.85	13.86	19.45	29.44	30.71	93.24	127.2	79.87	-
Zn_A	38.32	16.15	17.32	15.66	21.19	16.81	15.66	14.79	14.27	10.00	13.85	14.60	27.20	21.84	17.88	18.89	19.61	27.55	33.11	16.15	-
Zn_B	46.83	19.74	21.17	17.40	25.89	20.55	19.14	18.08	17.49	12.22	16.93	17.84	33.25	26.69	21.85	23.08	23.97	33.67	40.47	19.73	-
Zn_C	38.32	16.15	17.32	15.66	21.19	16.81	15.66	14.79	14.27	10.00	13.85	14.60	27.20	21.84	17.88	18.89	19.61	27.55	33.11	16.15	-
Zn_D	40.14	16.92	18.15	14.92	22.19	17.61	16.41	15.50	14.95	10.48	14.51	15.29	28.50	22.88	18.73	19.78	20.54	28.86	34.69	16.91	-

[1] *Suzuki et al.* (1993)

* A, B C and D indices at the elements denote the sampling areas of the desert soils (A and B are found at the North-eastern part, while C and D at the south-western part of the Takla Makan Desert) (*Suzuki et al.*, 1993)

Table 4b Non-crustal fractions of S, Cl, Cu and Zn relative to local samples of soil[1], North-western China, %

Element*	Sample No.																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
S_A	57	53	0	12	6	15	0	0	0	0	17	0	0	56	13	0	0	71	0	64	0
S_B	97	97	91	94	94	94	93	90	93	89	95	83	93	97	94	93	92	98	92	98	88
S_C	96	96	86	92	91	92	90	86	90	84	92	75	89	96	92	89	88	97	88	97	82
S_D	97	96	89	93	93	93	92	88	91	87	93	79	91	97	93	91	90	98	90	97	85
Cl_A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cl_B	88	93	91	96	94	95	93	90	93	95	84	76	79	85	87	75	81	97	93	81	84
Cl_C	63	48	72	87	82	84	80	70	79	85	91	28	38	54	61	25	43	91	79	43	52
Cl_D	59	42	69	86	80	83	78	66	77	83	90	20	32	49	56	17	37	90	77	36	47
Cu_A	99	98	97	98	98	98	97	97	98	98	98	-	76	92	94	96	96	99	99	99	-
Cu_B	100	99	99	99	99	99	99	99	99	99	99	-	90	97	98	98	98	100	100	99	-
Cu_C	95	88	83	85	86	85	84	84	85	86	87	-	0	47	62	75	76	92	94	91	-
Cu_D	99	98	98	98	98	98	98	98	98	98	98	-	79	93	95	97	97	99	99	99	-
Zn_A	97	94	94	94	95	94	94	93	93	90	93	93	96	95	94	95	95	96	97	94	-
Zn_B	98	95	95	94	96	95	95	94	94	92	96	94	97	96	95	96	96	97	98	95	-
Zn_C	97	94	94	94	95	94	94	93	93	90	93	93	96	95	94	95	95	96	97	94	-
Zn_D	98	94	94	93	95	94	94	94	93	90	93	93	96	96	95	95	95	97	97	94	-

[1] *Suzuki et al.* (1993)

* A, B C and D indexes at the elements denote the sampling areas of the desert soils (A and B are found at the North-eastern part, while C and D at the south-western part of the Takla Makan Desert) (*Suzuki et al.*, 1993)

Table 5a Enrichment factors of K, Ca and Mn relative to local samples of soil[1], North-western China

Element	Sample No.																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
K_A	1.71	2.04	1.87	1.68	1.85	1.92	1.82	1.72	1.72	1.86	1.76	1.60	1.80	1.73	1.92	1.90	2.06	2.49	2.01	1.79	1.81
K_B	0.88	1.05	0.96	0.86	0.95	0.99	0.93	0.88	0.88	0.95	0.90	0.82	0.92	0.89	0.98	0.98	1.06	1.28	1.03	0.92	0.93
K_C	0.76	0.90	0.83	0.74	0.82	0.85	0.81	0.76	0.76	0.82	0.78	0.71	0.80	0.77	0.85	0.84	0.91	1.11	0.89	0.79	0.80
K_D	0.74	0.88	0.81	0.73	0.80	0.83	0.79	0.74	0.75	0.81	0.76	0.69	0.78	0.75	0.83	0.83	0.90	1.08	0.87	0.78	0.79
Ca_A	2.10	2.31	3.79	3.74	3.05	2.94	3.17	2.57	3.02	2.98	2.97	2.97	2.88	1.98	2.63	3.39	2.97	3.59	2.14	1.73	2.30
Ca_B	1.70	1.87	2.74	3.02	2.47	2.37	2.56	2.08	2.44	2.41	2.40	2.40	2.33	1.60	2.12	2.74	2.40	2.90	1.73	1.40	1.86
Ca_C	0.91	1.00	1.46	1.61	1.32	1.27	1.37	1.11	1.30	1.29	1.28	1.28	1.24	0.85	1.13	1.46	1.28	1.55	0.92	0.74	0.99
Ca_D	0.75	0.82	1.21	1.33	1.09	1.05	1.13	0.92	1.08	1.06	1.06	1.06	1.03	0.71	0.94	1.21	1.06	1.28	0.76	0.62	0.82
Mn_A	1.22	1.47	1.07	0.86	0.81	0.99	1.25	0.99	0.96	0.73	0.91	0.63	1.35	1.31	1.25	1.02	1.57	2.26	1.10	1.54	0.84
Mn_B	1.28	1.53	1.12	0.90	0.84	1.04	1.31	1.04	1.00	0.76	0.95	0.66	1.41	1.37	1.30	1.07	1.64	2.36	1.15	1.61	0.88
Mn_C	1.04	1.25	0.91	0.73	0.69	0.85	1.06	0.85	0.82	0.62	0.78	0.54	1.15	1.11	1.06	0.87	1.34	1.92	0.94	1.32	0.72
Mn_D	1.17	1.41	1.02	0.82	0.77	0.95	1.20	0.95	0.92	0.70	0.87	0.60	1.29	1.25	1.19	0.98	1.50	2.16	1.06	1.48	0.81

[1] *Suzuki et al.* (1993)

* A, B C and D indices at the elements denote the sampling areas of the desert soils (A and B are found at the North-eastern part, while C and D at the south-western part of the Takla Makan Desert) (*Suzuki et al.*, 1993)

Table 5b Non-crustal fractions of K, Ca and Mn relative to local samples of soil[1], North-western China, %

Element	Sample No.																				
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*
K_A	42	51	47	40	46	48	45	42	42	46	43	37	44	42	48	47	51	60	50	44	55
K_B	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	22	3	0	0
K_C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0
K_D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0
Ca_A	52	57	71	73	67	66	68	61	67	66	66	66	65	49	62	71	66	72	53	42	57
Ca_B	41	47	64	67	60	58	61	52	59	59	58	58	57	37	53	64	58	66	42	29	46
Ca_C	0	0	32	38	24	21	27	10	23	22	22	22	19	0	12	32	22	35	0	0	0
Ca_D	0	0	17	25	8	5	12	0	7	6	6	6	3	0	0	17	6	22	0	0	0
Mn_A	18	32	7	0	0	0	20	0	0	0	0	0	26	24	20	2	36	56	9	35	0
Mn_B	22	35	11	0	0	4	24	4	0	0	0	0	29	27	23	7	39	58	13	38	0
Mn_C	4	20	0	0	0	0	6	0	0	0	0	0	13	10	6	0	25	48	0	24	0
Mn_D	15	29	2	0	0	0	17	0	0	0	0	0	22	20	16	0	33	54	6	32	0

[1] *Suzuki et al.* (1993)

* A, B C and D indices at the elements denote the sampling areas of the desert soils (A and B are found at the North-eastern part, while C and D at the south-western part of the Takla Makan Desert) (*Suzuki et al.*, 1993)

Near the Great Wall, in the vicinity of Beijing, S and Cl with highest enrichment factors were analyzed by *Winchester et al.* (1981a, 1981b). *Hashimoto et al.* (1994) collected samples with high concentration of chlorine in Urumqi, Xinjiang. Sulfur concentration was found also high over Lake Baikal (*Van Malderen et al.*, 1996) and Xizang (Tibet) (*Winchester and Wang*, 1989). However, similar results were obtained in Sudan, Africa (*Penkett et al., 1979*). *Penkett* and his co-workers attributed this finding to the disintegration of salt flats and to the evaporation of rainwater leaving a salt rich layer. High concentrations of S and Cl in the Namib Desert atmospheric aerosol content were confirmed by a marine contribution (*Annegarn et al.*, 1983).

The enrichment factors of copper and zinc counted relative to local samples of soil (*Suzuki et al.*, 1993), are also tabulated (*Table 4a*). Except for $EF_{Fe}(Cu)$ calculated for the sampling region C (*Suzuki et al.*, 1993) EFs are well over 20 at most sampling sites. Presumably, these elements are mostly emitted by anthropogenic sources. Scandium, chromium, nickel and barium are the elements, which can be detected at some sites with high concentrations, with enrichment factors well over 10, relating at least partly to their non-crustal origin, while at other sites their EFs are below 10 or even cannot be traced at all. In order to reveal potential spatial connections, the mentioned elements were marked at their sites on the map if their EFs were higher than 10 (*Fig. 2*). According to this map, significant non-mineral sources for scandium can be detected partly at the south-western region, partly at the eastern—north-eastern region of the Tarim Basin. Chromium has significant concentrations in the northern part of the Tarim Basin. Nickel, as an element mainly of non-crustal origin, can be measured with higher concentrations at the North-western part of the region. Barium can be ascribed to significant anthropogenic source at the southern fringe of the Tianshan Mountain (*Fig. 2*).

Enrichment factors of K, Ca and Mn, relative to local samples of soil (*Suzuki et al.*, 1993), were also calculated (*Table 5a*). Since in this case elemental concentrations in soil, with the exception of sampling region A for potassium, are also higher than those in the crust (*Table 3*), EFs of K, Ca and Mn decreased, respectively (*Table 5a*).

The $(c_x)^*$ fraction of the concentration of an element x, coming from non-crustal contribution, can be calculated by the following formula (*Mason*, 1966):

$$(c_x)^* = \frac{(c_x)_{air} - (c_{Ti})_{air} \cdot (\frac{c_x}{c_{Ti}})_{crust}}{(c_x)_{air}}, \text{ where} \qquad (3)$$

$(c_x)_{air}$: is the concentration of an element x in the air
$(c_{Ti})_{air}$: is the concentration of titanium in the air
$(c_x)_{crust}$: is the concentration of an element x in the crust
$(c_{Ti})_{crust}$: is the concentration of titanium in the crust.

The table of non-crustal fractions (*Table 6*) shows that an important part of potassium, vanadium, manganese and iron is released into the air from the Earth's crust. Potassium can have biological source. In spite of the fact that vanadium has a moderately high non-crustal fraction, we can conclude to its partial crustal origin. Manganese must be partly industry-orientated. Iron can be both of natural and anthropogenic origin. Mineral particles in North-western China contain high amount of Fe and can, therefore, be expected in the atmosphere. Their presence has also been reported in other desert areas, as well (*Penkett, et al.*, 1979; *Annegarn et al.*, 1983; *Shattuck et al.*, 1991). It is known on the other hand that ferrous metallurgy is a source of iron-rich particles, which might be of minor importance in our case, since heavy industry is only found in the region around Urumqi. Therefore, it is likely that the major part of iron is of natural origin. Quartz is one of the most widespread minerals in the Earth's crust. It is originated by weathering rocks, which might result in small particles easily dispersed into the atmosphere by winds. North-western China, with its deserts and steppes, arid and semi-arid regions, even with high mountains, surrounding the Tarim Basin, with slopes of which looking on to the basin and having practically no any vegetation, is one of the most important regions of the world where quartz is accumulated. Most of the Tarim Basin is covered by loose sandy soil, and shifting sand covers predominant part of the Takla Makan Desert, inside the basin. Therefore, it is not surprising that quartz particles are commonly observed and they have a substantial fraction on the filters. High concentrations of quartz in soil samples of the Takla Makan Desert are confirmed by *Suzuki et al.*, 1993. At two-thirds of the samples, the concentration of silicon was at least one order of magnitude higher than that of the other elements (*Table 2a-c*). Another source of Si-rich particles is the combustion of coal in power plants as discussed by *Husein* (1986), furthermore *Flagan and Taylor* (1981). Enrichment of silicon at sampling site No. 18. and its moderately high non-crustal fraction might be traced back to an industrial background near the site. Though non-crustal ratio of calcium is relatively high, it is originated mostly from the crust. The case of vanadium is quite different. On the basis of its moderately high non-mineral fraction, measured at some sites, we can conclude to its partial non-crustal origin. As it is well known, its emission comes mostly from oil burning. For several elements (S, Cl, Sc, Cr, Ni, Cu, Zn) the non-mineral fraction, calculated on the basis of average crust concentrations, is over 80 per cent; even for some of them (S, Cl, Cu, Zn) it is between 95 and 100 per cent (*Table 6*). While nickel and copper can be connected to non-ferrous metallurgy, and nickel is also emitted by coal and oil combustion in power plants and industrial boilers, zinc is mainly emitted from iron-, steel- or ferro-alloys plants (*Pacyna*, 1984). Other sources of Zn are refuse incineration (*Mamame*, 1988) and tire wear (*Hopke*, 1985). In the lack of enlarged heavy industry in Xinjiang Province, moderately high non-crustal fractions of vanadium and manganese as well as those of nickel and especially copper and zinc might probably indicate enrichment of these elements in local soil. has high non-crustal fractions. Scandium is rather enriched on the one hand at the south-western part, on the other hand at the north-eastern part of the Tarim Basin (*Table 2a-c, 6; Fig. 2*). This element might come mainly from oil burning. This hypothesis is to be confirmed by the fact that the two largest oil resources in the Tarim Basin can be found in the above-mentioned regions, and the scandium might come from their oil torches.

The enrichment factor for chromium was partly well over ten, but the sites for these concentrations are distributed at the northern part of the Tarim Basin. This indicates that chromium here is partly of non-crustal origin. These values are similar to those, which were measured over Hungary (*Borbély-Kiss et al.*, 1991; *Molnár et al.*, 1993a). This element was enriched at some regions, far from human settlements, as high as in the air over industrial areas. Chromium is regarded as an indicator of emission from the steel and iron industry. At the sites near Urumqi, concentration of Cr reflects the effect of the city which is an important centre of iron metallurgy. However, the only centre of iron and steel manufacturing in Xinjiang Province is hardly supposed to raise chromium concentrations thousands km away from Urumqi. It is also possible however, that chromium is of crustal origin (*Nriagu*, 1989a, 1989b) and its concentration in the soils of this area is higher than its crustal average (*Mason*, 1966). This latter hypothesis is supported by the fact that the highest chromium concentration was found at the southern fringe of the Takla Makan Desert

(*Molnár et al.*, 1993b). Chromium was detected in soil samples collected in the Takla Makan Desert but concentration data were not mentioned (*Suzuki et al.*, 1993). These data might confirm the above-mentioned hypothesis, according to which soils in the Tarim Basin are enriched in chromium relative to the crustal average.

Table 6 Non-crustal fractions of aerosol particles, relative to average crust data, %

Ele-	*Sample No., North-western China*																				
ment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Al	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Si	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0
S	100	99	98	99	98	99	99	99	99	98	99	96	99	100	99	99	98	100	98	100	98
Cl	99	98	99	100	99	99	99	99	99	99	100	97	98	99	99	97	98	100	99	98	98
K	29	41	23	17	0	23	17	17	17	17	23	3	23	29	29	23	37	72	29	29	23
Ca	67	69	75	79	58	71	73	69	72	69	83	70	71	64	69	76	74	89	60	57	64
Sc			92	95						96	93	97									92
Ti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V	69	80	23		52	37	29	50	33	0	0	9	47	77	52	23	47	91	52	72	9
Cr	62	90	79	68	79	79	67	85	81	89	78	80	69	93	68	78	78	98	70	94	50
Mn	47	57	29	17	0	23	37	23	17	0	17	0	44	50	41	29	55	84	29	55	9
Fe	23	23	9	9	0	9	9	9	9	0	9	0	9	23	9	9	17	57		17	9
Ni		83	63	74	82	80		86	82		70			90		74		96		85	
Cu	100	99	98	99	98	98	98	98	98	98	99		84	95	96	97	98	100	99	99	
Zn	99	97	98	96	96	96	96	96	96	93	96	96	98	98	97	97	97	99	98	97	
Ba		76	17									29	72	92	73		63	96	74	94	

The cases of sulfur and chlorine need a bit more attention. On the basis of their non-crustal fractions (96-100 per cent), they seem to be absolutely of non-mineral origin (*Table 6*). In order to understand why these enrichments occur in the two types of processes, it should be considered which one could be important in semiarid environments. In the first, case soluble salts are concentrated in the uppermost soil layers under conditions of alternating precipitation and evaporation and associated soil biological processes. The segregation of elements at the soil-air interface creates an opportunity for their preferential transfer to the atmosphere when dust is lifted. In the second case reactive acidic gaseous compounds, which are being present in the air from pollution or natural sources, attach to suspended basic dust particles. These might be subsequently deposited to the surface at rates that are controlled by aerosol mechanics. Chemical processes alone may drive soluble elements to the soil surface in alternating wet and dry conditions by capillary action. However, the process might be catalysed by algae and other desert flora that cover much of the soil surface. Since high salinities are toxic to flora, the organisms pump out salt to counteract internal salinity build-up during their dehydration, and crystals might be formed on the surface. It is known that periods of high humidity, which can create a more favourable salinity environment for desert flora than dry periods, stimulate algae growth. According to *Wang et al.* (1987), the above-mentioned mechanism for salt accumulation at the soil surface might be biological, although chemical processes provide a driving force. Nevertheless, these processes are consequences, which are actually quite effective. The main climatological and geomorphological factors, which are reasonable for salt accumulation in the Tarim Basin, are the relief and its extreme climate. This basin is a vast inland region without outflow. In the summer, cloudiness is almost negligible; consequently, sunshine radiation is very high, which increases potential evaporation as well as aridity, since there is hardly any precipitation in this season here. As the Tarim Basin has no any outflow, salt has been accumulating. The connected biological and chemical processes accelerate this procedure. Since the air over North-western China is highly enriched with sulfur and chlorine, the dry deposition flux of these elements to the surface should be large, although balanced by an equal flux upward (*Wang et al.*, 1987). In the thinly populated Xinjiang Province it can hardly be imagined that anthropogenic sulfur emissions can lead to more than a modest additional dry deposition sulphate flux. High enrichment factors of S and Cl (*Table 2a-c*) are decreased considerably when calculating them relative to local samples of soil (*Table 4a*), however high non-crustal fractions of these elements (*Table 6*) calculated relative to local soils are decreased only slightly and non-mineral fractions of sulfur and chlorine are well over 80 % in several cases (*Table 4b*).

Non-crustal fractions relative to local samples of soil for S, Cl, Cu and Zn (*Table 4b*) furthermore those for K, Ca and Mn (*Table 5b*) are less than those relative to earth crust (*Table 6*). Even though those for Cu and Zn indicate an important effect of non-mineral origin. Higher non-crustal fractions might come partly from long distance transport; however, disintegration of the surface is more probable.

Our results were compared with those of other arid and semiarid regions in China (*Molnár et al.*, 1993b), Sudan (*Penkett et al.*, 1979) and Namibia (*Annegarn et al.*, 1983; *Eltayeb et al.*, 1993), respectively. According to the data in Sudan, when winds blow from Sahara, the concentrations of different elements are very high. This coincides well with our results for the Takla Makan Desert (see also *Molnár et al.*, 1993b). As a characteristic difference, the concentration of sulfur and chlorine as well as chromium is substantially lower in Sudan and the Namib Desert than in the Takla Makan. Further difference is that S and Cl is of marine origin in the Namib natural aerosol.

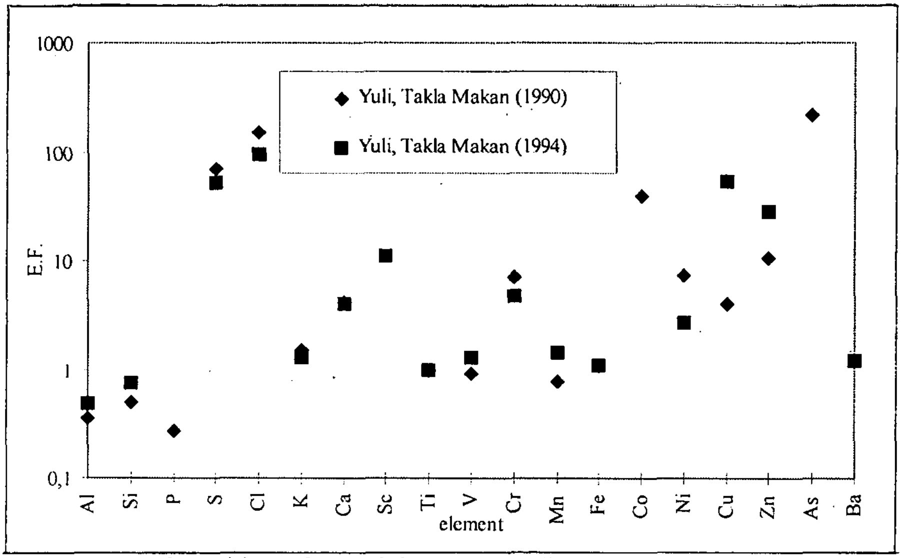
Results of the samplings measured at same three sites both in 1990 (*Molnár et al.*, 1993b) and in 1994 (present paper) were also compared (*Fig. 3a-c* and *Table 7*). [Bold letters indicate geographical positions and description of these three sampling sites (*Table 7*)]. The characteristic similarity of these three pairs of concentration series is that highly enriched sulfur and chlorine were detected equally in each site both in 1990 and in 1994.

Furthermore, enrichment factors of elements of soil origin [Al, Si, K, Mn and Fe (with EF near unity)] are very similar in the two measuring periods. However, concentration data were significantly higher in 1994 at each site analyzed. Especially the absolute concentrations of copper and zinc, respectively were one order of magnitude higher in 1994 than in 1990. The total concentration of elements of crustal origin (Al, Si, K, Mn, Fe and further taking S, Cl and Ca into this group) reaches 95-99 per cent of that of the detected elements. This shows that soil controls almost exclusively the quantity of aerosol over the region. Phosphorus, cobalt and arsenic were only detected in 1990 but barium and scandium only in 1994 (*Table 7*). Latter results, considering high enrichment of these elements except for phosphorus, might suppose some changes in non-mineral emissions.

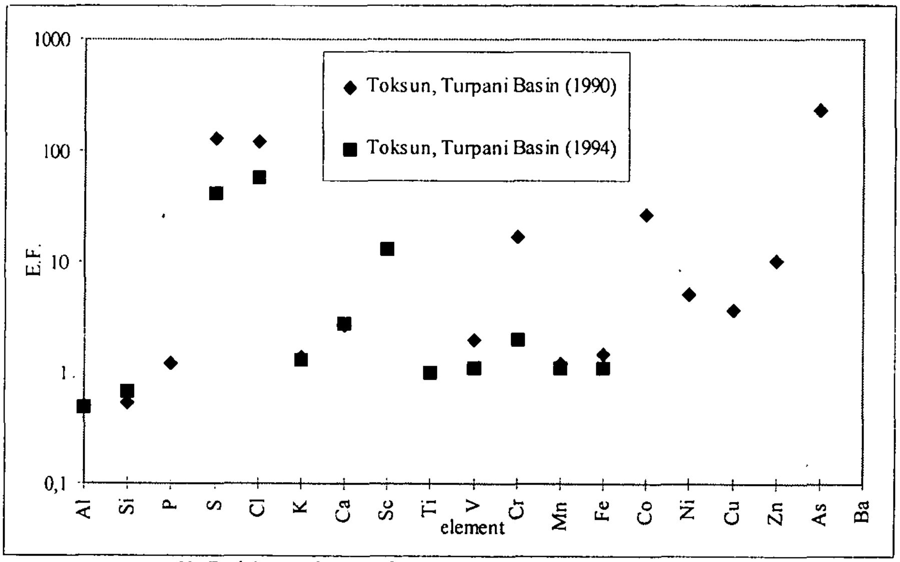
Table 7 Enrichment factors (EF) and concentration ratios of different elements in aerosol particles in North-western China

Element	*Yuli, Takla Makan (desert)*			*Toksun, Turpani Basin (lowland, desert)*			*Du-ku, Tianshan (mountain)*		
	EF 1990[1]	*EF 1994*[2]	$(c_x)_{1994}/(c_x)_{1990}$ [3]	*EF 1990*[1]	*EF 1994*[2]	$(c_x)_{1994}/(c_x)_{1990}$ [3]	*EF 1990*[1]	*EF 1994*[2]	$(c_x)_{1994}/(c_x)_{1990}$ [3]
Al	0.36	0.48	3.2	0.50	0.49	23.5	0.34	0.51	6.6
Si	0.50	0.75	3.6	0.54	0.67	30.5	0.43	0.64	6.6
P	0.27			1.2			1		
S	69.8	52.2	1.8	131.2	41.7	7.7	86.7	59.8	3.1
Cl	150.2	96.2	1.6	123.7	57.8	11.3	79.2	128.4	7.2
K	1.5	1.3	2.1	1.4	1.3	22.1	0.99	1.4	6.1
Ca	4.2	4	2.3	2.7	2.8	24.7	3.4	2.5	3.2
Sc		11			12.9				
Ti	=1	=1	2.4	=1	=1	24.2	=1	=1	4.5
V	0.92	1.3	3.3	2	1.1	13.1	2.2	2.1	5.4
Cr	7.1	4.7	1.6	17.1	2	2.8	12.6	3.3	1.2
Mn	0.78	1.4	4.2	1.2	1.1	21.8	0.62	1.4	9.9
Fe	1.1	1.1	2.3	1.5	1.1	18.2	1.2	1.04	4
Co	39.4			26.7			28.2		
Ni	7.5	2.7	0.9	5.2			2.7		
Cu	4.1	53.9	31.5	3.7			4.6	156.2	151.4
Zn	10.8	28.7	6.4	10.5			6.5	54	36.9
As	219.8			231.7			270.9		
Ba		1.2						3.9	

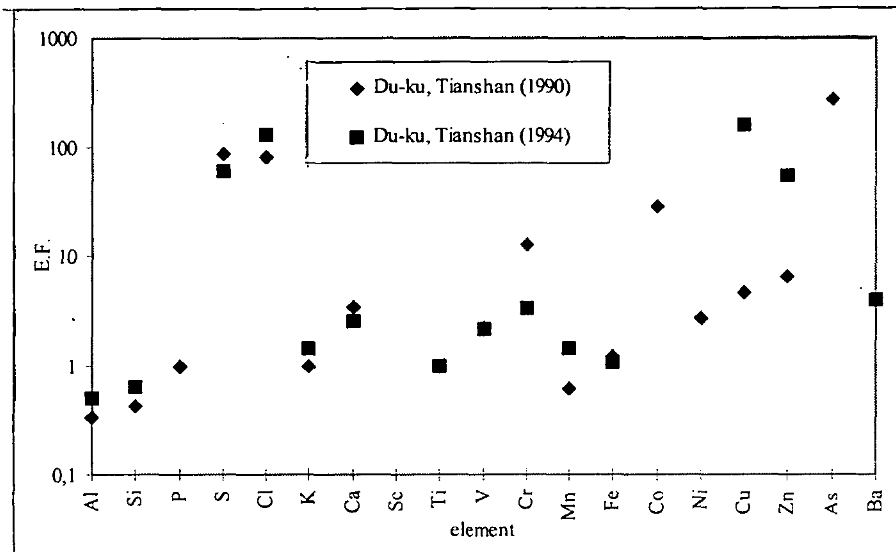
[1] *Molnár et al.* (1993)
[2] Present paper
[3] concentration of an element x measured in 1994 (present paper) relative to that measured in 1990 (*Molnár et al.*, 1993)



3a Enrichment factors of 19 elements at Yuli, Takla Makan Desert



3b Enrichment factors of 19 elements at Toksun, Turpani Basin



3c Enrichment factors of 19 elements at Du-ku, Tianshan Mts.

CONCLUSION

According to our results the absolute concentrations of S and Cl are surprisingly high in the Tarim Basin comparing to desertic regions in Africa. Besides the level of chromium is also very high. Those of *Wang et al.* (1987) and *Winchester and Wang* (1989) confirmed these results for sulfur and chlorine. Both papers show high sulfur concentration over North-western China and Xizang (Tibet). The sulfur content over Xizang is only relatively high; compared to that over Xinjiang it is nearly one order of magnitude lower. Sulfur and chlorine is enriched in Northern China (*Winchester et al.*, 1981a, 1981b), sulfur and chromium in the Lake Baikal region (*Van Malderen et al.*, 1996). [Sulfur content is also high in Chinese cities, which can be explained by coal burning. However, it is out of our field, since we study and compare (in China) only atmospheric aerosols of background regions without local anthropogenic sources.] The concentration of aerosols might change with seasons. In the winter, they probably get accumulated, while in the summer they are deluted. The examination of the seasonal change of the elemental concentration is the task of further research. Several papers of this kind of analysis have been published for urban areas of China with expressed seasonal change in concentrations (e.g. *Ning et al.*, 1996; *Hashimoto et al.*, 1994).

As a conclusion, the extremely high concentrations of S, Cl and the moderately high ones of Cr over North-western China, taking into account the surrounding large thinly populated regions, might not come from local anthropogenic sources. Local soil is highly enriched with sulfur and chlorine (ratios of these elements of local soil relative to those of crust are well over 1). Consequently enrichment factors of these elements relative to local samples of soil are near (at some cases below) 1. Therefore, it is clearly proved that the source of highly enriched sulfur and chlorine in atmospheric aerosols in North-western China is exclusively the local soil which is also highly enriched with salts. Concentration data of chromium in local soil are not available. Thus, enriched chromium in atmospheric aerosol particles can not be explained directly. However, it is presumed that Cr is also of soil origin. Enrichment factors of Cu and Zn even relative to local soil are well over ten. Hence, their non-crustal fractions are generally well over 80 % which assumes their mostly non-mineral origin. However, there are no industrial sites over the vast territories of North-western China. There are insufficient concentration data of copper and zinc in local soil; nevertheless, it is supposed that these elements also come from local soil.

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REFERENCES

Adams, F., Van Craen, M., Van Espen, P. and Andreuzzi, D., 1980: The elemental composition of atmospheric aerosol particles at Chacaltaya, Bolivia. *Atmos. Environ. 14,* 879-893.

Adams, F., Van Espen, P. and Maenhaut, W., 1983: Aerosol composition of Chacaltaya, Bolivia, as determined by size-fractionated sampling. *Atmos. Environ. 17,* 1521-1536.

Annegarn, H.J., Van Grieken, R.E. Bibby, D.M. and Von Blottnitz F., 1983: Background aerosol composition in the Namib Desert South West Africa (Namibia). *Atmos. Environ. 17,* 2045-2053.

Borbély-Kiss, I., Bozó, L., Koltay, E., Mészáros, E., Molnár, A. and Szabó, Gy., 1991: Elemental composition of aerosol particles under background conditions in Hungary. *Atmos. Environ. 25A,* 661-668.

Borbély-Kiss, I., Koltay, E., Szabó, Gy., Bozó, L., and Tar, K., 1999: Composition and sources of urban and rural atmospheric aerosol in Eastern Hungary. *J. Aerosol Sci. 30,* 369-391.

Domroes, M. and Peng, G.B., 1988: *The Climate of China.* Springer-Verlag, Berlin - Heidelberg - New York.

Eltayeb, M.A.H., Van Grieken, R.E., Maenhaut, W. and Annegarn, H.J., 1993: Aerosol-soil fractionation for Namib Desert samples. *Atmos. Environ. 27A,* 669-678.

Fan, X.B., Okada, K., Niimura, N., Kai, K., Arao, K., Shi, G,Y., Qin, Y. and Mitsuta Y., 1996: Mineral particles collected in China and Japan during the same Asian dust storm event. *Atmos. Environ. 30,* 347-351.

Flagan, R.C. and Taylor, D.D., 1981: Laboratory studies of submicron particles from coal combustion. *18th Symposium (International) on Combustion*, Pittsburgh, PA, 1227-1237.

Freney, J.R., Ivanov, M.V. and Rodhe, H., 1983: The Major Biogeochemical Cycles and their Interactions. eds. Bolin, B. and Cook, R.B. SCOPE 21 report. Wiley, New York. pp. 56-61.

Ge, S., Khalil, M.A.K. and Rau, J.A., 1989: The application of a chemical mass balance model in China. In *Receptor Models in Air Resources Management* (edited by Watson, J.G.), pp. 12-19. Air & Waste Management Association, Pittsburgh, PA.

Greenwood, N.N. and Earnshaw, A., 1997: *Chemistry of the Elements.* 2nd ed., Butterworth-Heinemann. 1834 p.

Hashimoto, Y., Sekine, Y., Kim, H.K., Chen, Z.L. and Yang, Z.M., 1994: Atmospheric fingerprints of East Asia, 1986-1991. An urgent record of aerosol analysis by the Jack Network. *Atmos. Environ. 28*, 1437-1445.

Hopke, P., 1985: *Receptor Modelling in Environmental Chemistry.* Wiley, New York.

Hu, Z.H., Zhong, M., Liu, Q.X., Zhong, H.H., Jiang, J.L. and Hu G.H., 1987: PIXE analysis of aerosols from the southern city Guangzhou. *Nucl. Instrum. and Meth. in Phys. Res. B22,* 283-288.

Husein, L., 1986: Chemical elements as tracers of pollutant transport to a rural area. In Toxic Metals in the Atmosphere (edited by Nriagu, J.Q. and Davidson, C.L.), *Advances in Environmental Science and Technology, 17,* Wiley, New York

Koltay, E., 1988: Particle induced X-ray emission: basic principles, instrumentation and interdisciplinary applications. In *X-ray Spectroscopy in Atomic and Solid State Physics* (edited by *Ferreira J.G. and Ramos, M.T.*). NATO Advanced Study Institute Series. Series B, Plenum Press, New York, *108,* 301-334.

Koltay, E., (1990) Elemental analysis of atmospheric aerosols: Results and perspectives of the PIXE technique. *International Journal of PIXE 1*, 93-112.

Maenhaut, W. and Malmqvist, K.G. (1992) Particle-induced X-ray emission analysis. In:*Handbook on X-ray spectrometry: Methods and techniques* (edited by Van Grieken, R. and Markowicz, A.A.), 517-581. Marcel Dekker Inc., New York.

Mamame, Y. and Noll, K.E., 1985: Characterization of large particles at a rural site in the eastern United States: Mass distribution and individual particle analysis. *Atmos. Environ. 19*, 611-622.

Mamame, Y., 1988: Estimate of municipal incinerator contribution to Philadelphia aerosol. I. Source analysis. *Atmos. Environ. 22*, 2411-2418.

Mason, B., 1966: *Principles of Geochemistry*. Wiley, New York.

Mészáros, E., 1978: Concentration of sulphur compounds in remote continental and oceanic areas. *Atmos. Environ. 12*, 699-705.

Molnár, Á., Mészáros, E., Bozó, L., Borbély-Kiss, I., Koltay, E. and Szabó, Gy., 1993a: Elemental composition of atmospheric aerosol particles under different conditions in Hungary. *Atmos. Environ. 27A*, 2457-2461.

Molnár Á., Makra, L., Chen Yaning and Borbély-Kiss, I., 1993b: Some data on the elemental composition of atmopsheric aerosol particles in Xinjiang, NW China. *Időjárás*, 97/3, 173-177.

Molnár, Á., Mészáros, E., Polyák, K., Borbély-Kiss, I., Koltay, E. and Szabó, Gy., 1995: Atmospheric budget of different elements in aerosol particles over Hungary. *Atmos. Environ. 29*, 1821-1828.

Morales, J.A., Hermoso, M., Serrano, J. and Sanhueza, E., 1990: Trace elements in the Venezuelan savannah atmosphere during dry and wet periods, with and without vegetation burning. *Atmos. Environ. 24A*, 407-414.

Ning, D.T., Liang, X.Z. and Chung, Y.S., 1996: Aerosol size distribution and elemental composition in urban areas of Northern China. Atmos. Environ. *30*, 2355-2362.

Nriagu, J.O., 1989a: A global assessment of natural sources of atmospheric trace metals. *Nature 338*, 47-49.

Nriagu, J.O., 1989b: Natural versus anthropogenic emissions of trace metals to the atmosphere. In: *Pacyna, J. and Ottar, B.* (Eds.): *Control and Fate of Atmospheric Trace Metals*. Kluwer Academic Publishers, 3-13.

Pacyna, J., 1984: Estimation of atmospheric emissions of trace elements from anthropogenic sources in Europe. *Atmos. Environ. 18*, 41-50.

Penkett, S.A., Atkins, D.H.F. and Unsworth, M.H., 1979: Chemical composition of the ambient aerosol in the Sudan Gezira. *Tellus 31*, 295-307.

Ren Mei'e, Yang R. and Bao H., 1985: *An outline of China's physical geography*. Foreign Language Press, Beijing.

Shattuck, T.W., Germani, S.G. and Buseck, P.H., 1991: Multivariate statistics for large data sets: applications to individual aerosol particles. *Analyt. Chem. 63*, 2646-2656.

Suzuki, K., Maeda, K., Sasa, Z., Okada, A., Sakamoto, K. and Ozawa, T., 1993: Application of PIXE to source identification of Kosa aerosol: analysis of desert soils in China. *Nuclear Instruments and Methods in Physics Research B75*, 317-320.

Van Malderen, H., Van Grieken, R., Khodzher, T., Obolkin, V. and Potemkin, V., 1996: Composition of individual aerosol particles above Lake Baikal, Siberia. *Atmos. Environ. 30*, 1453-1465.

Wang, M.X., Winchester, J.W. and Li, S.M., 1987: Aerosol composition in the drylands of North-western China. *Nucl. Instrum. and Meth. in Phys. Res. B22*, 275-282.

Winchester, J.W., Lü, W.X., Ren, L.X., Wang, M.X. and Maenhaut, W., 1981a: Fine and coarse aerosol composition from a rural area in North China. *Atmos. Environ. 15*, 933-937.

Winchester, J.W., Wang, M.X., Ren, L.X., Lü, W.X., Hansson, H.C., Lannefors, H., Darzi. M. and Leslie, C.D.A., 1981b: Nonurban aerosol composition near Beijing, China. *Nucl. Instrum. and Meth. in Phys. Res. 181*, 391-398.

Winchester, J.W. and Wang, M.X., 1989: Acid-base balance in aerosol components of the Asia-Pacific region. *Tellus 41B*, 323-337.

Xhoffer, C., Bernard, P. and Van Grieken, R., 1991: Chemical characterization and source apportionment of individual aerosol particles over the North Sea and the English Channel using multivariate technics. *Envir. Sci. Technol. 25*, 1470-1478.

Xu, J., Hu, H. and Zhou, J., 1991: Model study of atmospheric aerosols in some typical places of China. *J. Aerosol Sci. 22*, S625-S628.

Zelenka, M.P., Wilson, W.E., Chow, J.C. and Lioy, P.J., 1994: A combined TTFA/CMB receptor modeling approach and its application to air pollution sources in China. *Atmos. Environ. 28*, 1425-1435.

Zhang, X.Y., Arimoto, R., An, Z.S., Chen, T., Zhang, G.Y., Zhu, G.H. and Wang, X,F., 1993: Atmospheric trace elements over source regions for Chinese dust: concentrations, sources and atmospheric deposition on the Loess Plateau. *Atmos. Environ. 27A*, 2051-2067.

Zou, L.Y. and Hooper, M.A., 1997: Size-resolved airborne particles and their morphology in Central Djakarta. *Atmos. Environ. 31*, 1167-1172.

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IDENTIFYING AN UNDESCRIBED DANCKERTS ATLAS

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Összefoglalás - 1997-ben a szegedi József Attila Tudományegyetem Földrajzi Tanszékeinek Könyvtárában felbukkant egy eddig ismeretlen Danckerts atlasz. A mű pontos leírása és meghatározása során kiderült, hogy ez egy rendkívül ritka, szép és értékes, ám sajnos hiányos, a XVII. század végéről származó munka. A kutatás folyamán felszínre került tények felhívták a figyelmet arra, hogy a mértékadó nemzetközi szakirodalomban is több módosításra szoruló adat és elképzelés található.

Summary - In 1997 a heretofore unknown Danckerts atlas has come to light in the Library of Geography Departments of József Attila University (Szeged, Hungary). Scrutiny for identifying the work has resulted in establishing the volume as a remnant of an extremely rare and precious work from the late 17th century. The examination has also drawn attention to the necessary modification of recently accepted notions of the international carto-bibliography concerning the producing and publishing history of the Danckerts atlases.

Key words: map history, late 17th century Dutch atlas cartography, Danckerts family, Danckerts works, categories of Danckerts world atlases, identifying, collation.

INTRODUCTION

In February 1997, looking for books in the Library of Geography Departments of József Attila University (Szeged, Hungary), one of the authors hit upon an externally simple and plain volume among the atlases. To his great surprise, however, it turned out to be a volume comprising maps by Danckerts. Identifying the work with help of the library's catalogue and the inventory yielded no result for its catalogue card with description was missing and the noting in the inventory was anything but satisfying (*Fig. 1*). It was so raised the necessity for searching and finding out more and more accurate information concerning the given volume.

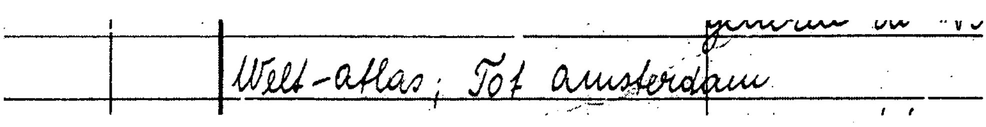

Fig. 1 The note of the inventory

The question can be brought up in the reader, of course, who is not so well up in the field of history of cartography and of carto-bibliography: what could be the importance of the emergence of the Danckerts atlas yet undescribed? A number of specialists, foreign and Hungarian (*Keuning*, 1955; *Stegena*, 1985; *Welu*, 1987; *Klinghammer*, 1995; *Wawrik*, 1995) are of the same opinion in that the Danckerts family was an outstanding representative of the 17th century Dutch cartography which at that time held a leading position in the field of mapmaking and -publishing in the world. "The characteristics of the atlas maps by the Danckerts, compared with those of other map publishers in Amsterdam are: they are clear and their scales are mostly larger than that of other maps of the period. Their cartographic works, compared with that published by the Blaeus or Janssonius[1], are attractive" (*Koeman*, 1969) (*Fig. 2, Fig. 3*). An author is also to be found who sees the most gifted copper-engraver of the 17th century in the person of Justus (I) (1635-1701), one of the members of the Danckerts family (*Allen*, 1994). Notwithstanding the concurring opinions, papers dealing in details with the Danckerts's life and their activity cannot almost be found. It is especially true of their atlases, the most important reason of which derives from the fact that only a very small amount of Danckerts atlases are recently known.

For arriving at a more successful examination and a better evaluation of the given Danckerts atlas work we had first and foremost to survey the available data referring to the Danckerts and their atlases.

THE DANCKERTS FAMILY

The Danckerts family (*Fig. 4*) was very large and ramifying having had a lot of members who were active in engraving on an artistic level. In this short view, however, we are dealing mainly with those who took part in the atlas production. As we will see, the biographical data give good assistance in determining the age of the Danckerts atlas guarded in József Attila University, Szeged.

The family's roots can be traced back to Cornelis Danckerts (1536-1595), a carpenter in Amsterdam. From his marriage with Lijsbet Cornelisdr two sons are known: Cornelis Danckerts de Rij (1561-1634) and Danckert Cornelisz (ca. 1580-1625). Cornelis and his descendants called themselves Danckerts de Rij. Danckerts Cornelisz who is at the root of the line we are now interested in was first a skipper then a stone merchant. He married Lijstbeth Jansdr, shortly after the turn of the century. Several members of his branch were well-known engravers-etchers, mapmakers and printsellers (*Keuning*, 1955). Danckert Cornelisz had two sons: Cornelis Danckerts (1603-1656) and Dancker Danckerts (1614-?).

Cornelis the elder brother established himself as an engraver, map- and artprint producer, printer and publisher in Amsterdam in the early 1630s. His shop was flourishing under his, the father's and his sons' and grandsons' direction in the second half of the 17th century as far as 1717 when the grandson Cornelis died. (Hereafter for distinguishing Cornelis the firm's founder and Cornelis, the grandson, Cornelis (I) and Cornelis (II) will be used,

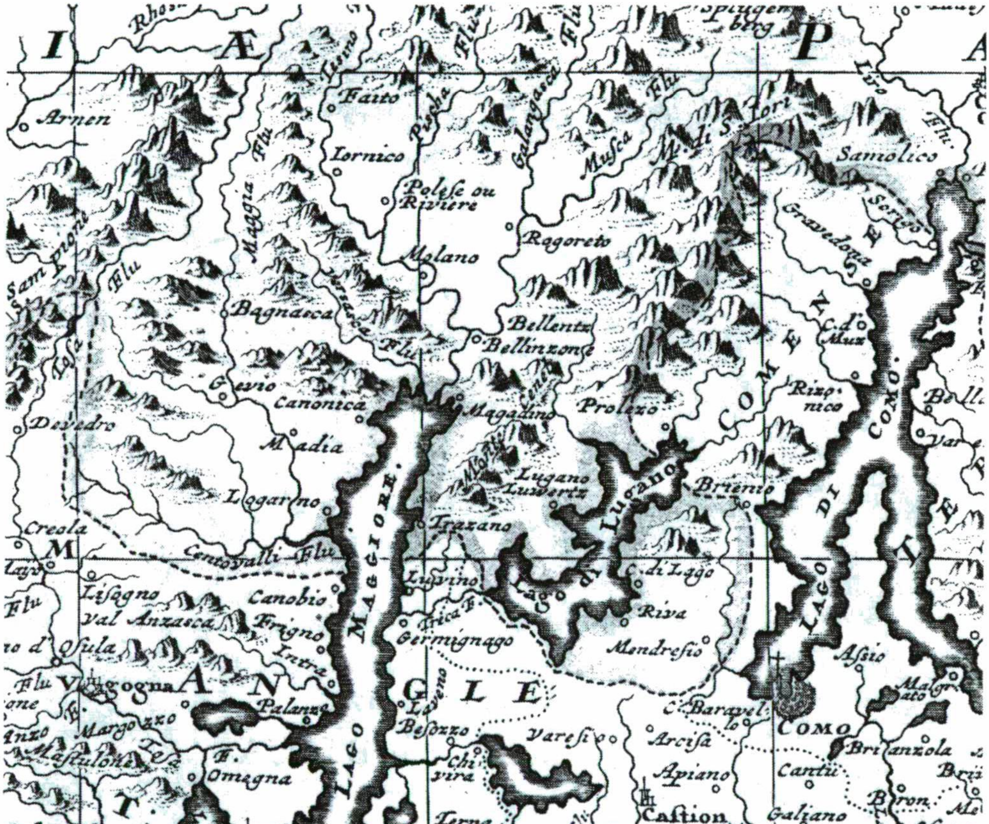

Fig. 2 A part of the map No. 13

Fig. 3 A part of the map No. 9

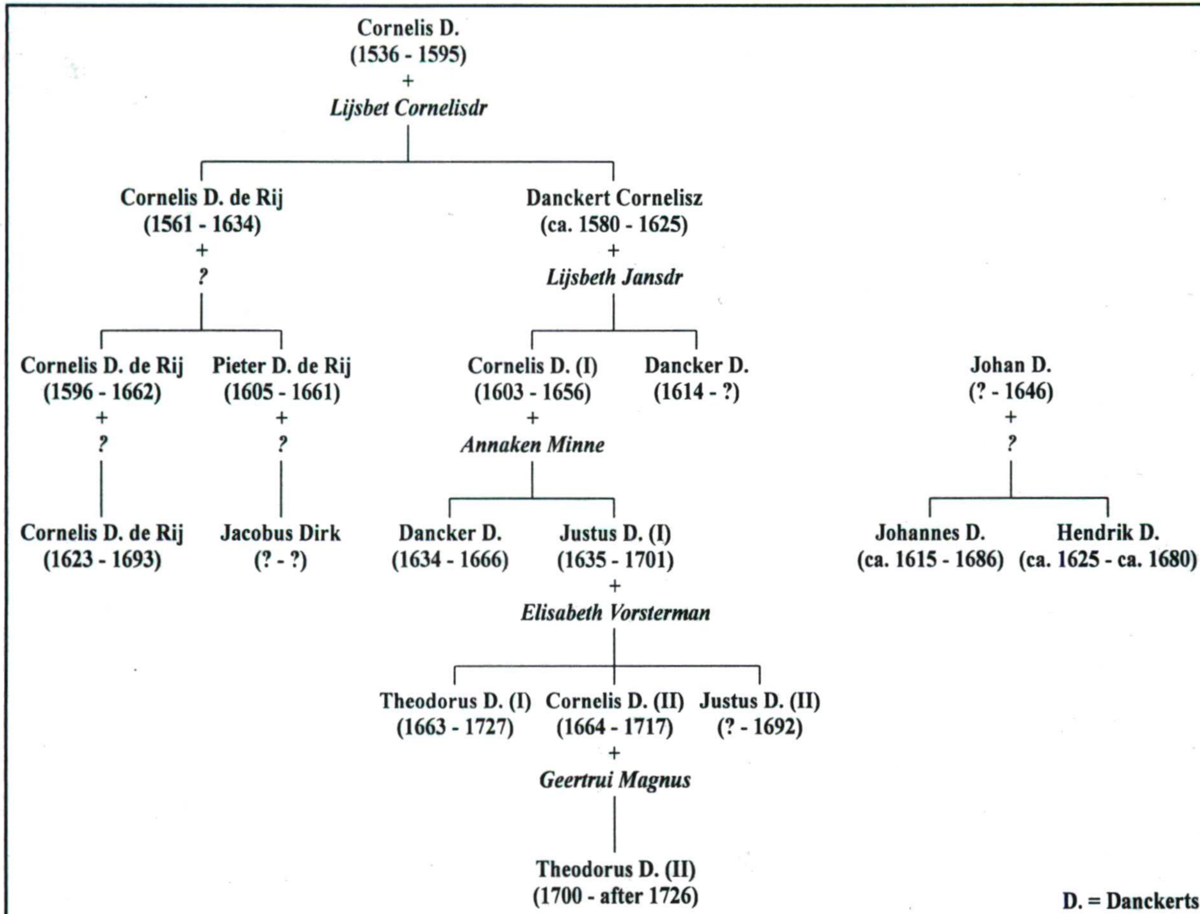

Fig. 4 The family tree of the Danckerts'

respectively.) Cornelis (I) was an eminent engraver producing a number of single-sheet maps and wall maps. Besides his own publications, he was working for reknown personalities of the time such as the famous John Speed (1552-1629), historian and mapmaker, "the father of the English atlases" or for Petrus Bertius (1565-1629), the illustrious geography professor at Leiden University (*Tooley*, 1979).

At Cornelis (I)' death (1656), the elder son, Dancker (1634-1666) took the shop over then at his early passing the younger brother Justus (1635-1701) who had been a stone merchant succeded his brother in direction of the firm. (As distinguishing marks (I) will be used at Justus, the father's name and (II) at the son's.) The Danckerts family's map producing and -publishing office had its apogee at the time of Justus (I) and of his three sons Theodorus (I) (1663-1727), Cornelis (II) (1664-1717) and Justus (II) (?-1692).

Between 1669-1701 their shop was run in the "Calverstraet in the Danckbaerheyt" (Danckbaerheyt=Thankfulness). Cornelis (II) married Geertrui Magnus, the daughter of a famous contemporary Amsterdam bookbinder, Albert Magnus and moved into the house of Magnus' widow on the "Nieuwendijk in de Atlas". (Albert Magnus had died some years before.) Thus after 1696 two print shops of the Danckerts were being run in Amsterdam and from that time onwards on different publications, also on maps and on atlas' title- and index-pages, Cornelis (II) used this new address.

The Danckerts's firm's closing down was gradually taking place. The first harder breaking could be caused by the general depression in 1713 when Justus (I)' heirs decided to sell a part of the map and atlas stock with lots of copperplates. The final, full stopping occured at the time of the last surviving brother, Theodorus (I) in 1727 when the remaining estate was also sold.

The copperplates of the maps were bought by Reiner and Josua Ottens, first-rate Amsterdam map- and atlas publishers in the first part of the 18th century. Following the general custom of the time, the Ottens erased the Danckerts names and addresses replacing them with their own (*Koeman*, 1969).

DANCKERTS ATLASES

Roughly 300 single-sheet maps, wall maps and art-prints can be connected with the Danckerts name (*Vries*, 1986). About compiling atlases by Danckerts, there is very few and partly contradicting information[2].

In the second part of the 17th century and in the early 18th century lots of Dutch composite atlases were assembled from different authors' maps[3].

Maps by Danckerts can also be found in such atlases, even the Danckerts atlas' title-page was also used by other publishers or collectors. But as mentioned above, only a few atlas volumes are known which were compiled by the Danckerts themselves from their own maps.

The atlases by the Danckerts have a clear structure. There is a title-page, an index for the maps, sometimes printed on the back of the title-page. No preliminary text can be found and text on the verso of the maps are also not included. The sequence of the maps begins with a world map (sometimes a celestial chart), then the maps of the four continents are coming, afterwards the sheets of differrent countries, of their territories and provincies, regionally arranged. The Danckerts atlases as other 16th to 18th century atlases, however, comprise mainly the maps of European territories, independently of the complete sum of the maps. We have known atlases by Danckerts with lots of different sums of maps. There are atlases with 25 maps, atlases with 29, 49, 74, 90, 93, 98, 100 maps, but from the confusing data, a clear structure can be deciphered only with hard work.

Fortunately, the "Atlas Neerlandici" (ed. by *C. Koeman*), a general bibliography of the Dutch atlases published up to 1880, however, tried it. In this bibliography the following categorization of the Danckerts world atlases can be found:

1. Atlas with printed index, listing 26 items (including the title-page + 25 maps).
   4 copies are certain to exist: Newberry Libr., Chicago (1); Engelbrecht Coll., Maritime Mus., Rotterdam (1); Saltykov-Sjtsjredin' Publ. Libr., Sankt Peterburg (1); Nat. Libr., Vienna (1).
2. Atlas with printed index, listing 30 items (title-page + 29 maps).
   3 copies mentioned: Libr. Ac. of Science, Cracow (1); Brit. Mus., London (2).
3. Atlas with ca. 60 maps.
   No copies mentioned.
4. Atlas with number of maps varying between 74 and 90.
   3 copies mentioned: Engelbrecht Coll., Maritime Mus., Rotterdam (2); Libr. of Congr., Washington D.C. (1)
5. Atlas with printed index, listing 100 items.
   3 copies mentioned: Univ. Libr., Amsterdam (1); Yale Univ., New Haven (1); Libr. of Congr., Washington D.C. (1)[4] (*Koeman*, 1969).

In this grouping it is striking that the compiler separated a particular category No. 3 but without mentioning any copy of it. This indicates such copies' existence as the compiler of the classification must have come to know such volume or volumes, at least from some sources. As we will see, the attempt for an identification of the Szeged Danckerts atlas and for giving a bibliographical description has proved the existence of an atlas of this group, moreover, it has queried the validity of this classification.

THE SZEGED ATLAS

The given atlas in the holdings of the Library of Geography Departments of József Attila University at Szeged, Hungary has the inventory number: 3486 and stock sign: D 179. The volume is 52x31 cm large, bound into half leather-cloth and comprises 26 maps with publisher's hand-written numbering in their upper right corner (out of the maps' frame) (*Fig. 5*). The map sheets were printed from copperplates, hand-coloured and are in a good condition. No particular notes or glosses printed or manuscript can be seen on the maps (on the recto or

Fig. 5 A part of the map No. 11

verso), not even a note referring to provenience which could facilitate clearing up the one-time possessor or possessors, only the proprietory seal of the Geographical Institute of the Szeged University can be detected.

We could conclude from this that the Danckerts atlas must have got to the holdings of the Geographical Institute no later than 1962 (when the university was renamed). It is conceivable that the work had come to the holdings even in Kolozsvár (now Cluj-Napoca, Romania) before the university removed to Szeged after the World War I as the Library of the Geographical Institute possessed roughly 2000 books and some 3000 map sheets in around 1925. It cannot naturally be precluded that the atlas arrived only with those large acquisitions which took place by purchases and donations in the mid-1920s.

With no title-page, index and its truncated condition (lots of maps are missing), the correct determination and bibliographical description of the volume seemed almost impossible. However, the numbering and its defects in the upper right corner of the pages suggested that we faced a remnant of a once complete work. The missing maps could be dispersed at any time in tempests of history or in several (?) bindings could be named as the real cause. (Skilless hands made nasty cuttings on the mapsheets' margins, very possibly at bindings.)

For all of these above mentioned reasons we saw that the chance for the volume's identification would be received only by collating it to other Danckerts atlases. The international carto-bibliography and map history referring to the history of Danckerts production activity knows as we mentioned previously, only a few Danckerts atlases. Even those 3 volumes have been unknown internationally which are held in the Map Department of the National Széchényi Library[5] as we concluded during research. These atlases are as follows:

1. Atlas with printed index, listing 26 items. TA 225 (OSZK). (25 maps = Atlantes Neerlandici catalogue, category 1).
2. Atlas with printed index, listing 50 items. TA 224 (OSZK). (49 maps = Atlantes Neerlandici catalogue, category 3 (?)).
3. Atlas with printed index, listing 100 items. TA 232 (OSZK). (98 maps = Atlantes Neerlandici catalogue, category 5).

The detailed collation of the Szeged Danckerts atlas to the OSZK atlases concluded in a surprising result. TA 224 (OSZK) and D 179 (JATE) showed a very close coincidence (*Table 1*). *Table 1* speaks for itself and the conclusion is that the D 179 (JATE) Danckerts atlas can be identified as a remnant of a Danckerts atlas with 50 items. Moreover, the two volumes seemed to be variations as only 4 differences in map title could be deciphered after collating each of the 25 mutual map sheets, namely in the maps No. 7, 34, 38, 48. The small differences in these maps' titles are always the same: name Theodorus substitutes for name Justus. (But who is behind name Justus could not be known with certainty; Justus (I) or Justus (II) or both. Name Theodorus surely covers Theodorus (I)). The Szeged copy is far more incomplete but the sheet No. 36 can be found only in D 179 (JATE) and is missing from TA 224 (OSZK).

Fixing the publication date of the Szeged atlas turned out to be a hard problem. "Seeing the custom of leaving maps undated become especially in vogue in the second half of

Table 1 The content and authors of maps of the TA 224 (OSZK) and D 179 (JATE) atlases.

NO.	ITEM *The names are identical with those of the index in the atlas TA 224 (OSZK)*	AUTHOR TA 224 (OSZK)	 D 179 (JATE)
1.	Atlas	+	—
2.	Nova Orbis Tabula	Justus D.	—
3.	America	Justus D.	—
4.	Africa	Justus D.	—
5.	Asia	Justus D.	—
6.	Europa	Justus D.	—
7.	Portugallia	Justus D.	Theodorus D.
8.	Hispania	Justus D.	—
9.	Gallia	Justus D.	Justus D.
10.	Italia, Corsica & Sardinia	Justus D.	—
11.	Mare Mediterraneum Occidentalis	Justus D.	Justus D.
12.	Mare Mediterraneum Orientalis	Justus D.	—
13.	Sabaudia & Piemontium	Justus D.	Justus D.
14.	Helvetia	Justus D.	Justus D.
15.	Germania	Justus D.	Justus D.
16.	Rhenus Fluvius	Justus D.	Justus D.
17.	Rhenus Superior	Theodorus D.	Theodorus D.
18.	Rhenus Inferior	Theodorus D.	Theodorus D.
19.	Lotharingia Ducatus	Theodorus D.	—
20.	Franconia	Theodorus D.	Theodorus D.
21.	Bohemia	Theodorus D.	—
22.	Danubii Fluvii	Theodorus D.	—
23.	Circulus Westphalicus	Justus D.	Justus D.
24.	Circulus Saxonicus	Justus D.	—
25.	Leodiensis & Coloniensis	Theodorus D.	Theodorus D.
26.	Germania Inferior	Justus D.	—
27.	Belgium Foederatum	—	—
28.	Hollandia Comitatus	Justus D.	Justus D.
29.	Ultrajectum Dominium	Justus D.	Justus D.
30.	Geldria Ducatus	Justus D.	Justus D.
31.	Belgii Regii	Justus D.	Justus D.
32.	Flandria Comitatus	Theodorus D.	Theodorus D.
33.	Hannonia Comitatus	Theodorus D.	Theodorus D.
34.	Namurcum Comitatus	Justus D.	Theodorus D.
35.	Luxemburgum Ducatus	—	—
36.	Brabantia Ducatus	—	Justus D.
37.	Anglia, Scotia & Hibernia	Justus D.	—
38.	Canalis	Justus D.	Theodorus D.
39.	Dania Regnum	Justus D.	—
40.	Suecia & Norvegia	Justus D.	—
41.	Polonia & Lithuania	Justus D.	Justus D.
42.	Hungaria	—	—
43.	Hungaria & Graecia	Justus D.	—
44.	Civitates Hungariae	—	—
45.	Morea	Justus D.	Justus D.
46.	Civitates Moreae	Justus D.	Justus D.
47.	Russia vulgo Moscovia	Justus D.	Justus D.
48.	Turcicum Imperium	Justus D.	Theodorus D.
49.	Judaea sive Terra Sancta	Theodorus D.	—
50.	Nova Belgica & Pensilvania	Justus D.	—

the 17th century. In this case only the content of a map can sometimes give the answer as regards its date." (*Keuning*, 1955). In our incident we used a similar method. Setting out from the fact that the TA 224 (OSZK) and D 179 (JATE) atlases proved to be very close variations of each other, our task shifted to determine the publishing date of the TA 224 (OSZK) atlas firstly as this copy is more complete in any aspects.

On the title-page of the TA 224 (OSZK) atlas the following inscription can be seen: "ATLAS / TOT AMSTERDAM / bij IUSTUS DANCKERS in de Calverstraet in de Dancbaerheijt". As we had known, the Danckerts shop was being run at this address between 1669-1701 (*Koeman*, 1969), so a conclusion arouse: TA 224 (OSZK) must have been published in the 1669-1701 period. A more precise date could only be hoped from a scrutiny of the maps themselves. Lots of maps bear a privilege[6] lettering in different forms that the Danckerts family was granted by the States of Holland and West Frisia: "cum Previlegio Ordinum Holland: et West-vrisiae" (*Fig. 6*), "cum Privil: Ordin: Hollandiae et West-frisiae" or "met Privilegio" etc. From biographical data we had known, the granting to Danckerts occured on August 14, 1684, so the edition of the atlas must have been taken place only after this time. The publishing epoch could be, however, even narrowed down as the map sheet No. 43 delineating Hungary and its surroundings (or more precisely the theatre of war between Christian and Turkish Muslim powers from 1683 onwards), has a list of towns and fortresses (in the lower left corner) with occupation dates by the Turks and recapturing dates by the Christians, respectively. The last line in this list is as follows: "Belgrado exp. 1529. rec. 1688". For us it meant that the TA 224 (OSZK) atlas could only be issued after this date, between 1688 and 1701[7].

But a question for dating atlas D 179 (JATE) still remained open: what state of the missing map No. 43 from the atlas D 179 (JATE) could have been? For 5 states of the "Regni Hungariae..." map have recently been known. State 1684 or later (*Szántai*, 1996); State 1687 (TA 225 (OSZK)); State 1688 (TA 224 (OSZK) and *Szántai*, 1996); and other 2 states[8] by Johannes Danckerts and that by Philip Bouttats junior and Justus Danckerts. Which state could have been originally incorporated in D 179 (JATE) atlas? The state 1684, state 1687, 1688? Or even an earlier version by Johannes or Dancker?

This question looked crucial for trying to tie atlas D 179 (JATE) to atlas TA 224 (OSZK). How could we choose? Resolving this problem and with it the problem of publishing date of D 179 (JATE) seemed to be determined only in one way: a collation of all maps in those atlases which have detailed bibliographical description or known by ourselves personally[9]. (Atlantes Neerlandici/Danl-Dan5 and TA 224 (OSZK), TA 225 (OSZK), TA 232 (OSZK), D 179 (JATE)).

If we sum up shortly the result, the scrutiny has led to a conclusion that the Danckerts atlas with 50 sheets could not possibly be ready at the time of privilege granting in 1684 and the earliest issuing could be occured at ca. 1687/88.

How did we gain this probability? The departing point was the privilege wordings. There are two types of Danckerts maps in this aspect: there is a privilege sign on the map or there is not. We had known that in the late 17th century Amsterdam, the map producers, against

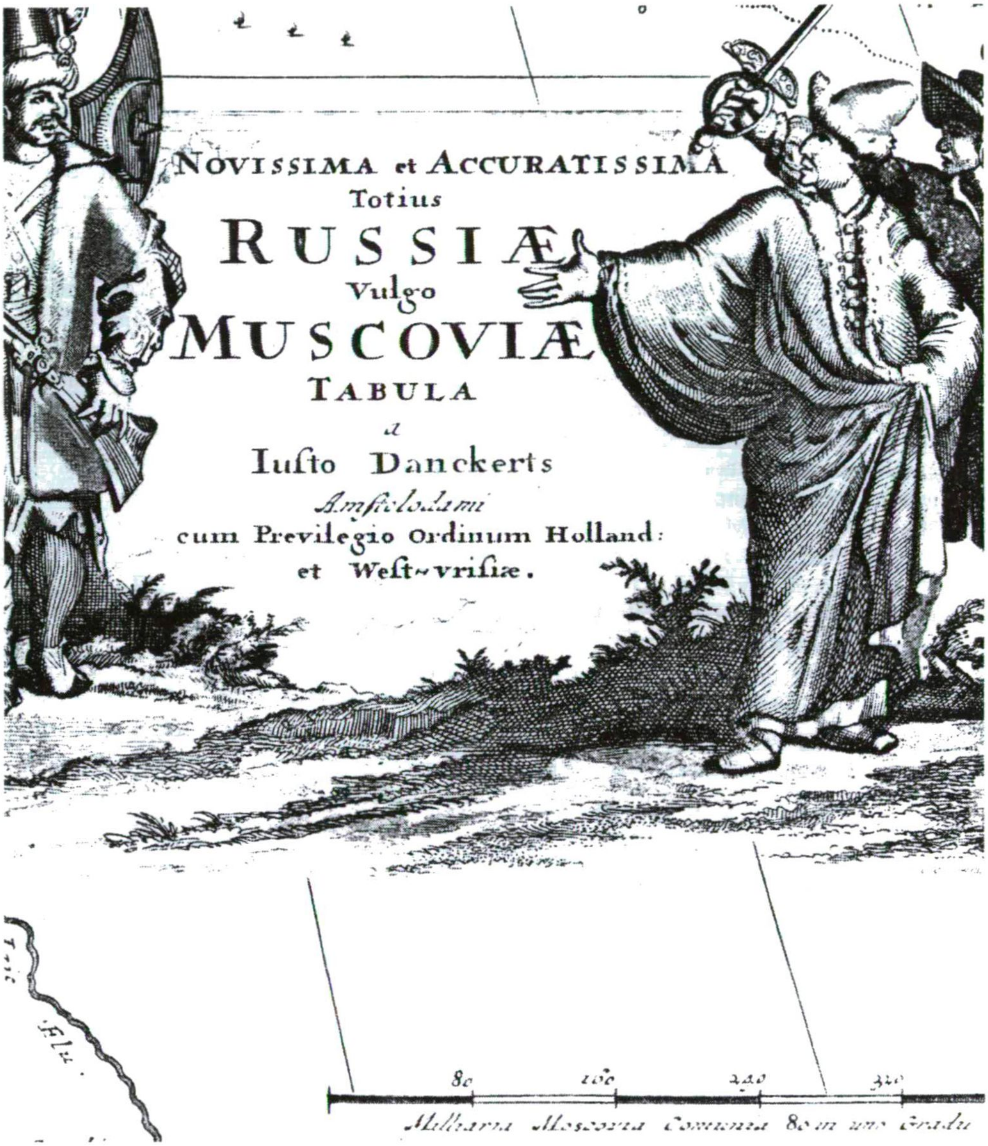

Fig. 6 A part of the map No. 47

their rivals' illegal using or plagiarising, regularly put their gotten privilege on their maps. Moreover, we noticed that the number of the maps with privilege are growing in those atlases which have more and more pages. Even a tendency could be realized: the later states of the same map got the privilege lettering but the other direction could hardly be detected: removing a privilege wording from the map. So the basic guess for the start was as follows: maps without privilege were made before 1684 (August 14)[10].

With scrutinizing the privilege inscriptions and the different states of each particular map, the following result could be gained: before 1684 the Danckerts family could have only 17 (18) maps of their own[11] ready for a complete geographical atlas. The maps of important regions, around the half of Europe had been waited for producing[12]. They were only ready at the time of privilege granting in 1684 or shortly before. These maps were those of Switzerland, of the British Isles, of Scandinavia, of Poland, of Russia, of "Regni Hungariae...", of the Peloponnesos and of the Turkish Empire that is the northern, eastern, southeastern and some middle parts of Europe. With these 8 new maps, the Danckerts stock for a complete atlas became essentially ready and this collection was later enlarged mainly with maps of provinces and parts of the different European countries (first and foremost with those of Germany, France, Netherlands, and Italy).

For an atlas with ca. 50 maps, as the D 179 (JATE) and TA 224 (OSZK), the Danckerts had to produce some more 24 new maps. If we calculate the time needed to the engravers for ca. 24 maps, in light of the speed the engravers of the age worked, we can count roughly another 2-3 years. That is ca. 1686/87, which figure strengthens that the D 179 (JATE) atlas had very unlikely been assembled before that time[13].

However, knowing the contemporary custom of the stock producing of maps that is the practice of printing a fairly large quantity of the maps before compiling them into an atlas, the chance of including an earlier state of the "Regni Hungariae..." map could not totally be excluded[14].

At this stage of scrutiny, an unexpected, lucky turn happened. While we were going over the pages of atlas TA 225 (OSZK) again (who knows how many times) it was happily noticed that there were recapturing dates also on the body of the Peloponnesos map and the latest one was 1687. This marvellous accident played the solution of the dating atlas D 179 (JATE) into our hand (concerning at least the lower limit of publication date) as the Peloponnesos map is incorporated also into D 179 (JATE) and has survived truncations (*Fig. 7*). We could so state that maps in the Danckerts's atlas guarded at Szeged must have been assembled at least in 1687 or later, and as a "by-product" the date 1687 on Peloponnesos map stenghtened our previous collations' result, too.

After determining the lower limit of the publishing date, we could turn to the upper one. The question arose: could we tighten the date at this side, too? In this scrutiny Cornelis (II) was our "associate". From a reference book (*Shirley*, 1984) it could be gained that Cornelis (II) most probably started his map-maker's carrier in the 1690s. His known world map derived from ca. 1695, a reworking of the map made by Justus (I) in ca. 1680 and he used his new address on his maps after 1696 (moreover, we considered the early passing of Justus (II), too

Fig. 7 A part of the map No. 45

(1692)). The survey of his maps in atlases listing 26, 50 and 75 items came to a result that the first maps of Cornelis (II) appeared only in the atlas with 74 maps (i.e. 8 in all in the Atlantes Neerlandici/Dan3). Determining the possible compiling date of a Danckerts atlas with ca. 75 maps could be figured out in the same way as we had done in the case of atlas with ca. 50 maps, that is for other 25 maps to 50 another 2-3 years must have been needed on the average to arrive at a complete Danckerts atlas comprising 75 maps[15]. The calculated date of such an atlas' compiling could be in 1688/89 or in the early 90s considering that the atlases with 50 pages we have recently known were assembled into atlases in 1687 (D 179 (JATE)) and 1688 (TA 224 (OSZK)) or later.

In this way, our final suggestion for the publishing date of the two Danckerts atlases with 50 items (49 maps + title-page) that is of D 179 (JATE) and of TA 224 (OSZK) can be placed between 1687, 1688 and 1695/96 with certainty or even we can take the risk saying 1687-1692 for D 179 (JATE) and 1688-1692 for TA 224 (OSZK). And finally, the periods 1687-ca. 1690 and 1688-ca. 1690 cannot also be unconceivable for D 179 (JATE) and TA 224 (OSZK), respectively. Further examinations, collations with other Danckerts atlases and making use of further new information will judge these provisional proposals of ours.

CONCLUSION

In the first place we can establish that the Danckerts atlas in Szeged compiled originally as an atlas with 49 maps in 1687-ca. 1695 proved to have real worth for the history of cartography, even in its truncated, bad condition.

The examination carried out for its identification resulted in some valuable outcomes. Firstly, the quantity of known original Danckerts atlases can be enlarged with 4 copies: TA 224 (OSZK), TA 225 (OSZK), TA 232 (OSZK) and D 179 (JATE). Secondly, it has thrown some more light on the ambiguous history of the Danckerts atlas production.

In addition, it has absolutely become settled that category 3 with ca. 60 maps (in the Atlantes Neerlandici bibliography) hides an actually existing Danckerts atlas. Moreover, the atlas of 50 items has turned out to have at the spot two variations and the emergence of the two Danckerts atlases of 50 pages points to a revision of recently accepted categorization of the Danckerts atlases. For this revision, further research will be necessitated, however, the following changes for category 3 can be even now offered:

1. Atlas with an exact quantity of items: title + index + 49 maps (and not ca. 60 maps).
2. Atlas comprising maps between 50 and 60 (as 74-90 in the case of group 4).
3. Atlas with 50 sheets can form a separate group (as atlas of 26 items and of 30 items forms a detached class), so the system must be enlarged to 6 groups in this case.

Item, some rationale would be found in separating also category 4 into other two detached ones.

This classification, nevertheless, seems to be regarded as only a preliminary, outlined approach and a future thoroughful collation in a broader circle of survived Danckerts atlases will certainly change our recent notions on the atlases. By the assistance of coming examinations, as in the case of identifying D 179 (JATE) volume, more light will hopefully be thrown on the very obscure publishing history of the Danckerts atlases.

NOTES

[1] Blaeu and Janssonius are two famous names in the Dutch map-making history. Their officinas were dominating in the field of geographical atlas production and had an almost total monopoly on the market of atlases during the century till ca. 1660s-70s.

[2] *Koeman* (1969) suggests that atlas producing started in the 1660s, *Wawrik* (1985) had confidence in the 1670s, while *Shirley* (1984) would accept a later date, ca. 1680.

[3] Even giant wall map composite atlases can be mentioned from the 1660s, the famous "Klencke Atlas", now in London; the "Atlas des Herzogs von Mecklenburg" in Rostock; and the "Mauritius Atlas" in Berlin.

[4] Having seen the rareness of the Danckerts atlases in public collection, a logical thought of going to the matter of privately owned Danckerts atlases came into our minds. Surveying the approximate quantity of those atlases, however, only the selling lists at auction were at our disposal. Having looked through all The Map Collector's issues between 1977 and 1996 and the sketchy selected lists in Mercator's World's numbers of 1996-1998, only 2 other Danckerts atlases could be discovered roughly in a 20-year period. (The Map Collector, No. 24, 1983 September, p.56. – atlas of 93 maps; The Map Collector, No. 30, 1985 March, p. 55. – atlas of 100 maps.) So as to realize the rarity of the Danckerts atlases, it is also worth mentioning the case of the famous 16th century basic atlas work, Theatrum Orbis Terrarum by Abraham Ortelius. As *Van den Broecke* (1986) calculated: from each edition of the atlas which was issued more than 30 times between 1570 and 1612, 30-40 volumes exist on the average, while the total sum of the Theatrum survived is over 500 copies.

[5] The National Széchényi Library possesses an important collection of atlases produced in the 16th and 17th century Netherlands including 3 almost complete, "hidden" Danckerts atlases.

[6] In the late 17th century the States customarily gave firms privileges for 10 or even 15 years as exclusive rights for selling maps, atlases or other prints of their own.

[7] Belgrade was retaken by the Christian troops on September 6, 1688. As we have known, producing a completely new map of a contemporary (war or other) event needed approximately a year (*Heinz*, 1997). In our case, however, only minute changes must have been done on the copper-plate – the TA 225 (OSZK) atlas has the same map with the same list missing only the last line from the list referring to Belgrade.

[8] The issuing dates of the later two maps are fairly obscure. Johannes Danckerts was a cousin of Justus (I). The "Regni Hungariae..." map with his name in the map's title have recently become known only from late Danckerts atlases by Theodorus (I) (TA 232 (OSZK)) and Cornelis (II) (*Szántai*, 1996), but the question who actually made this map, Justus (I) or Justus (II) or Johannes or even Dancker (1634-1666) has not been solved yet. (Dancker's name as engraver can be seen on certain states of the plate). Philip Bouttats junior was active in Antwerp as a member of an engraver and publisher family. A rather close variation of the "Regni Hungariae..." map by Philip's relative Gaspar Bouttats also exists. Most probably both of them used the Danckerts maps as source for their own versions edited at the time of the Turkish wars sometimes in the late 17th century. The Philip's version has a list of fortresses with the last date 1687 at Eger, Hungary. Eger was recaptured on December 16, 1687, so this state of the map could came out from print only in or after 1687. (*Szántai*, 1996 mentioning 1688, but seems not to know the Justus version of 1687.)

[9] We used, of course, every information at collation we had owned of the Danckerts family and the producing and publishing practice in Amsterdam in the 17th-18th centuries that we have gathered from reference books or periodicals.

[10] There could be exceptions, that maps without privilege sign are still after 1684. However, their numbers are only a few and these are second-rate maps for an atlas. They depict provinces, districts or towns and fortresses and do not belong to the most important maps of the world, of the continents, of countries wich formed (and still form) the skeleton of a geographical atlas.

[11] Map of the world, of the four continents, of Germania, of Gallia (=France), of Hispania, of Portugal, of Italy, of Denmark, of the XVII Provinces (=the Netherlands and Belgium), of Comitatus Hollandia, of Ducatus Geldria et Zuthpania, of the river Rhine, of Circulus Saxoniae, of Hungary by Du Val, and of Novi Belgii (=the eastern part of North America) that is the maps of the world, of the continents, of the western parts of Europe and those territories which were mostly of interest to the purchasers of the time mainly in the Low Countries. The Geldria map could be found, however, only in atlases with 49 or more maps.

[12] Maps of smaller areas, regions, provinces or districts of other continents were far less important in a general atlas in the 16-17th centuries and their ratio stood far behind of those counterparts in Europe.

[13] In special circumstances, engravers could produce a map plate roughly in a month even trough a longer period of time, but we must calculate that Justus (I) was in his 50s after 1685 probably dealing with the selling part of the business and the burden of compiling and engraving must have lied mainly on the shoulders of the young Theodorus (I) and maybe of Justus (II). Theodorus (I) was in his early 20s and Justus (II) – if he was born in 1665/66 – could be in the same age but with 2 years younger.

[14] The quantity which was printed from a newly engraved or an emended plate varied at each territory and could depend even on very particular circumstances. Here it's worth mentioning that the other Hungary-map by Pierre Du Val which was reworked by Justus Danckerts could be the sheet No. 42 in atlas D 179 (JATE), as in the atlas TA 224 (OSZK). This map can be found in every atlas that had been examined, with or without a privilege sign.

[15] It could have been possible that the Danckerts family compiled an atlas with 74 maps using other author's maps but the total number of their maps in atlases we have known seems to make this unlikely.

REFERENCES

Allen, Ph., 1994: *Atlas of atlases* (in Hungarian). Budakönyvek Kft., Budapest, 86.

Broecke, M.P.R. van den, 1986: Facts and speculations on production and survival of Ortelius Theatrum Orbis Terrarum and its maps. *The Map Collector 36*, 2-12.

Heinz, M., 1997: A programme for map publishing. The Homann firm in the eighteenth century. *Imago Mundi 49*, 104-115.

Keuning, J., 1955: Cornelis Danckerts and his "Nieuw Aerdsch Pleyn". *Imago Mundi 12*, 136-139.

Klinghammer, I., 1995: Maps in history (in Hungarian). In: *Klinghammer, I., Pápay, Gy. and Török, Zs.*, 1995: *History of Cartography* (in Hungarian). ELTE Eötvös Kiadó, Budapest, 14.

Koeman, C., 1961: *Collections of maps and atlases in the Netherlands. Their history and present state.* E.J. Brill, Leiden, 30-32.

Koeman, C. (ed.), 1969: *Atlantes Neerlandici. Bibliography of terrestial, maritime and celestial atlases and pilot guides, published in the Netherland up to 1880. Vol. 2*, Theatrum Orbis Terrarum Ltd., Amsterdam, 88-97.

Shirley, R.W., 1984: Cornelis Danckerts. In: *Shirley, R.W.*, 1984: *The mapping of the world. Early printed world maps. 1472-1700.* The Holland Press Ltd., London, 563.

Shirley, R.W., 1988: *Printed maps of the British Isles. 1650-1750.* Map Collector Publications Ltd. – The British Library, Tring, Hertfordshire – London, 48-49.

Stegena, L., 1985: *History of cartography* (in Hungarian). 4th edition. Tankönyvkiadó, Budapest, 82.

Szántai, L., 1996: *Atlas Hungaricus. Printed maps on Hungary. 1528-1850* (in Hungarian). Akadémiai Kiadó, Budapest, 134-141.

Tooley, R.V., (comp.) 1979: *Tooley's dictionary of mapmakers*. Map Collector Publications Ltd., Tring, Hertfordshire, 145-146.

Vries, D. de, 1986: Danckerts (Familie). In: *Kretschmer, I., Dörflinger, J. and Wawrik, F.* (eds.), 1986: *Lexikon zur Geschichte der Kartographie. Von den Anfangen bis zum ersten Weltkrieg.* Franz Deuticke, Wien, 150.

Wawrik, F., 1985: *Die berühmte Atlanten. Kartographische Kunst aus fünf Jahrhunderten.* Harenberg, Dortmund, 117-121.

Wawrik, F., 1995: Renaissance- und Barockatlanten. In: *Vierhundert Jahre Mercator vierhundert Jahre Atlas. "Die ganze Welt zwischen zwei Buchdeckeln". Eine Geschichte der Atlanten.* Hrsg. von Hans Wolff im Auftr. der Bayerischen Staatsbibliothek. A. H. Konrad, Weissenhorn in Bayern, 52.

Welu, J.A., 1987: The sources and development of cartographic ornamentation in the Netherlands. In: *Woodward, D.* (ed.), 1987: *Art and cartography. Six historical essays.* The University of Chicago Press, Chicago – London, 147-173.

The Map Collector 24, 1983 September, 56.

The Map Collector 30, 1985 March, 55.

CONTENTS

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