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GEOCHEMICAL INFLUENCES ON DENTAL DISEASE

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Abstract: In several recent epidemiological studies, it has been suggested that geochemical factors influence human health and disease. Among the clearest evidence are the geographic variations in the expression of dental diseases among living and prehistoric populations. For example, school children in the state of Missouri U. S. A., have a wide range of caries scores among geochemical regions. Furthermore, in several of these regions the anticaries affects of fluorides appear to be reduced by some geochemical component. Prehistoric native Americans who lived in these same regions also had significantly higher rates of dental caries. Similarities in dental disease patterns among geochemical regions for extant and extinct populations cannot be adequately explained with dietary or socioeconomic factors. Therefore, it is possible that microelements in the soils and waters of these regions may be responsible for the variations.

Preliminary studies of skeletal remains from Hungarian populations of the Avar and more recent periods also show geographic distributions of dental caries that are similar to those seen in Missouri. Comparisons of caries epidemiological data for Hungary and Missouri enable inferences to be made concerning Interrelationships between dental health and geochemical factors.

Key words: Geochemical factors, Dental caries, Missouri school children, Prehistoric inhabitants of Missouri, Avar period in Hungary.

Introduction

Many experimental and epidemiological studies in recent years have documented the requirements of several microelements for normal growth (Prasad, 1985). In addition to elements like iodine and iron which have been known to be essential for human health since ancient times, newer ones like copper, zinc and selenium have been added to a growing list. This group now consists of 15 elements which are recognized or suspected as being required in trace amounts (Underwood 1981). The interest in mineral metabolism and the expanded research in this area has added fluorine and strontium as probably essential to mineralized tissue development. The use of fluorine in the treatment of osteoporosis as well as its cariostatic influence as documented by thousands of studies certainly supports the function of this element (see Curzon and Cutress, 1983).

The bio-availability of both the major and microelements varies widely in any environment, hence the ability of the human population to absorb the complex nutrients and elements will depend upon the population's subsistence base and upon the geochemistry of their habitat. Barmes and his associates (1970) showed, for example, a diversity of chemical elements absorbed by native New Guineans because of the differences between their geochemical environments. This study, as well as numerous others, have stimulated a growing concern with the health effects of natural geological components of the environment (Hemphill, 1977; Cannon, 1978). It is not easy, however, to establish such interrelationships because of the complexity of geochemical interactions and because of the diversity of the human diet. Broad surveys of populations in a variety of environments, therefore, are useful to develop generalizations which then may be examined closely to determine the exact geochemical components which affect human health. The mineralized tissues, especially teeth, provide a useful and nearly permanent record of microelement influence.

Our interest in the skeletal and dental tissues and microelement influence is that of anthropologists. In addition to an interest in morphology, a particular concern is the question of why do some peoples, past or contemporary, have healthier teeth and bones than do others? The occurrence of skeletal and dental pathologies often varied geographically, even among those peoples who had similar diets and living habits. Since the frequencies of pathologies cannot be explained on the basis of diet alone, some other environmental factor or factors must have been involved. In order to investigate these factors, we embarked upon a series of broad studies which were designed to collect data on the geographical diversity of dental diseases. The major geochemical components of the natural environment were also identified for each region of those populations sampled.

Our initial study, conducted as a pilot project, consisted of three data sets from two collections of skeletal remains of extinct populations and a dental health survey of contemporary school children. The first survey was an examination of dental disease of prehistoric native Americans of the state of Missouri, U. S. A. This was followed by the collation of records gained from a dental health survey of Missouri school children conducted in 1983–84. These two data sets were compared to the state's geochemical regions. That is, the geochemical region of the residences of the contemporary population were compared as was the geographic distribution of the prehistoric skeletons. The third data set was gathered as part of an ongoing study of dental disease of prehistoric and earlier Hungarian populations (see Molnar and Molnar 1985). These data sets offer an opportunity to compare the distribution of certain dental diseases with the geochemical features of two world regions. Our preliminary results are described below.

The Data Sets

Dental Survey of Missouri School Children

The Bureau of Dental Health for the state of Missouri conducted a caries survey of second and sixth grade school children, averaging seven and twelve years old,respectively. Large metropolitan areas such as St. Louis and Kansas City were excluded. Only those children residing in the smaller rural communities were examined so a residentially stable population sample could be collected. The length of time that a child had resided within the community was determined by means of consent and questionaire forms which were completed by the parents. Our study included only those children who had been lifelong residents of areas where fluoride content of the drinking water could be determined. Those who had changed residences during their lifetimes or who had been exposed to a mixture of fluoridated and nonfluoridated drinking water were not used in the study. Data on decayed, missing and filled teeth were entered in the data set for 6.584 children from population centers shown in Figure 1A. These population localities were then related to geochemical regions defined by data from a geological survey of the state.

Geochemical Regions

A comprehensive geochemical survey was recently completed for the state of Missouri, U. S. A. (Cannon, 1978). Approximately 7.000 samples were analyzed for thirty to forty geochemical factors including concentrations of trace elements, hydrogen ions, nitrates, sulfates and carbonates. From these data over 150 geochemical maps have been produced. Two types of maps were useful in our survey of dental disease distributions: (1) those depicting geochemical variation among ground and surface waters which were produced to describe microelement concentrations among the major hydrologic systems in Missouri (Feder 1979) and (2) those depicting microelement variation among soils of the state (Erdman et al., 1976). Seven conceptual geohydrologic units were defined on the basis of geologic stratigraphy (Figure 1B). The classification of soils is based on natural vegetative areas (Figure 1C). These are the regions of vegetation types which would exist if the area would be allowed to revert to its natural state (Erdman, et al. 1976).

Figure 1A. Population Centers of School Children

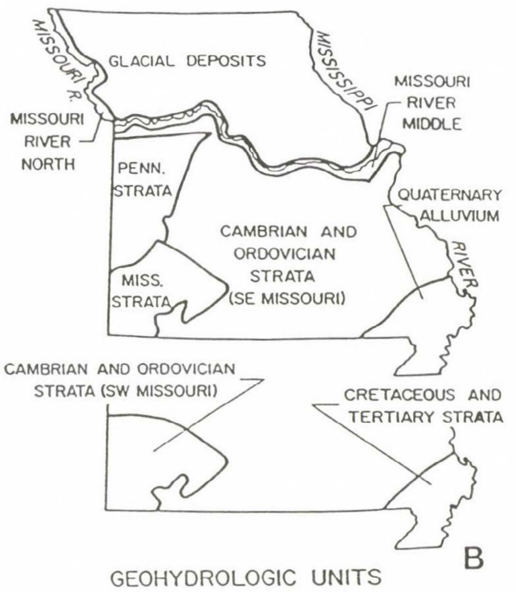

Figure 1B. Geohydrologic Limits of Missouri

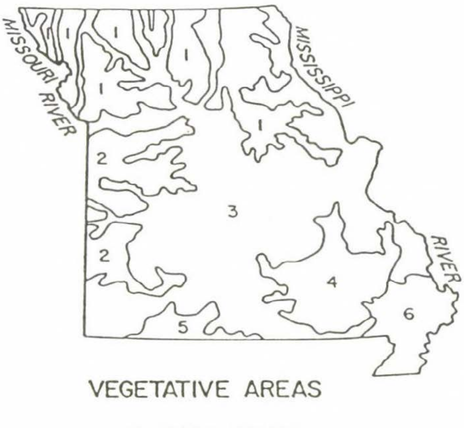

Figure 1C. Vegetative Areas of Missouri

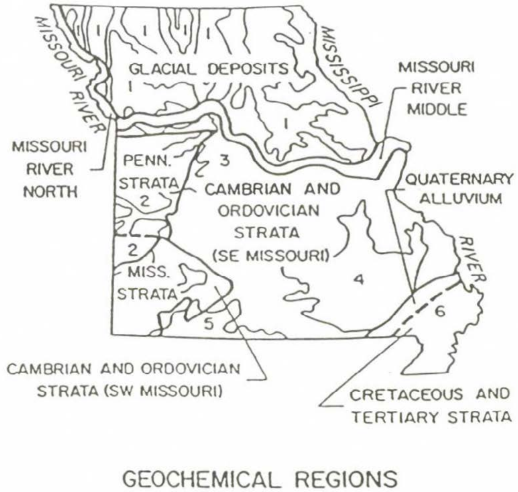

Figure 1D. Geochemical Regions

We created a map which combined the features of both geohydrological units with those of the vegetative areas to produce a "geochemical regions", map (Figure 1D). Though there is some variation of chemical components within each region, there is a greater range of difference between geochemical regions. The boundaries of these regions, therefore, depict units whose microelement compositions differ at significant levels (Feder 1979; Erdman, et al. (1976). We refer to these regions throughout the paper by the initials listed next to each appropriate hydrologic unit plus its vegetative description (Table 1). For example, the initials COSECG identifies the southern central position of the state which had a presumbed natural "cedar glades" vegetative cover overlying a "Camberian-Ordivician" geologic substrata.

Table 1. Geochemical regions state of Missouri

COSECG	Cambrian Ordivician East, Cedar Glades
COSWCG	Cambrian Ordivician West, Cedar Glades
COSWOHF	Cambrian Ordivician West, Oak-Hickory Forest
MSOHF	Mississippian Oak-Hickory Forest
PENNOHF	Pennsylvanian Oak-Hickory Forest
MRMUGP	Missouri River Middle, Unglaciated Prairie
MRNOHF	Missouri River North Oak-Hickory Forest
MRNGP	Missouri River North, Glaciated Prairie
GDGP	Glacial Deposits, Glaciated Prairie
MRMOHF	Missouri Middle Oak-Hickory Forest
GDOHF	Glacial Deposits, Oak-Hickory Forst
COSEOHF	Cambrian-Ordivician East, Oak-Hickory Forest
BGDGP	Deep Glacial Deposits, Glaciated Prairie
DGOOHF	Deep Glacial Deposits, Oak-Hickory Forest
QAFF	Quarternary Alluvium-Flood Plain Forest

Caries Scores for Missouri School Children

The mean caries scores were determined for four groups of children within each of 15 geochemical regions (see Table 2). Differences in means among regions were tested statistically by analysis of variance (ANOVA). Pairwise comparisons between and within regions were performed where appropriate (Student's t-test). Pairwise comparisons were also performed for children drinking fluoridated versus nonfluoridated water for ten regions. Figures 2A, B, C, D are computer enhanced plots of means caries scores which graphically depict regional distributions.

For children of the second grade drinking nonfluoridated water, there are significantly higher caries incidences in MSOHF and MRNGP than in other regions (Figure 2A). The children of the QAFF, COSWOHF, COSWCG and COSEOHF also tend to have high mean caries scores, but these do not differ significantly from the low means. The lowest scores were for the children of MRMUGP, MRMOHF, GDOHF and COSECG.

Among six graders drinking nonfluoridated water, all of the caries scores are lower than those of the younger children because of the recent eruption of permanent teeth between eight and twelve years of age. There are some interesting contrasts between scores for different regions. The highest incidences of caries were foung in children of the MRNOHF, MRMOHF, QAFF and MSOHF whose means scores were significantly different from those of the children of the other regions (Figure 2B). Children of the COSWOHF, COSWCG, and MRMUGP have the lowest while the children of the remaining regions have intermediate values.

As expected sixth graders drinking fluoridated water generally had lower scores (Figure 2C). However, there were significant differences between regions. Incidences of caries were highest in children of the DGDGP and QAFF regions. Significantly lower incidences were recorded for MRMOHF, MRNOHF and MRMUGP. The communities in these three

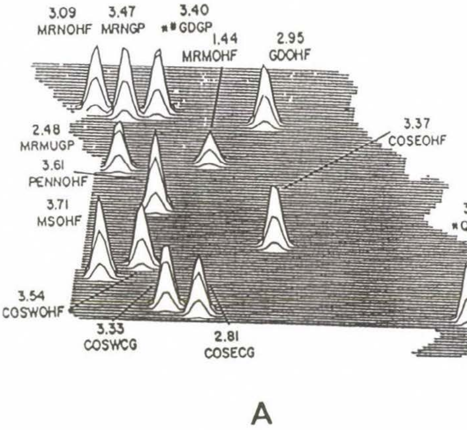

Figure 2A. Mean Caries Scores; Second Grade School Children Drinking Nonfluoridated Water

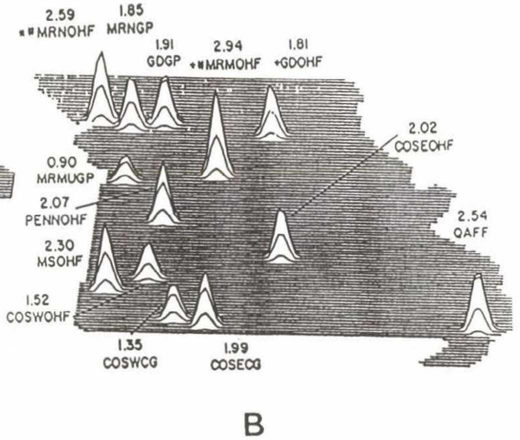

Figure 2B. Mean Caries Scores; Sixth Grade School Children Drinking Nonfluoridated Water

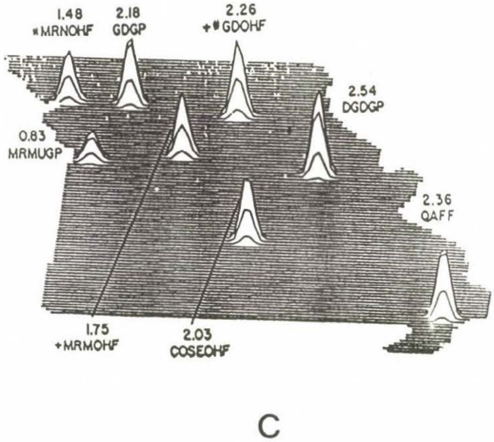

Figure 2C. Mean Caries Scores; Sixth Grade School Children Drinking Fluoridated Water

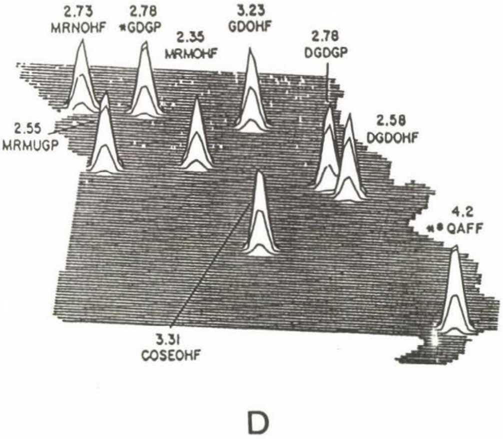

Figure 2D. Mean Caries Scores; Second Grade School Children Drinking Fluoridated Water

Table 2. Mean caries scores Missouri school children*

Geochemical Region		Water Supplies	
		Non-Fluoridated	Fluoridated
COSECG			
Age:	12 years	1.99	–
	7 years	2.81	–
COSWCG			
Age:	12 years	1.35	–
	7 years	3.33	–
COSWOHF			
Age:	12 years	1.52	–
	7 years	3.54	–
MSOHF			
Age:	12 years	2.30	–
	7 years	3.71	–
PENNOHF			
Age:	12 years	2.07	–
	7 years	3.61	–
MRMUGP			
Age:	12 years	0,90	0.83
	7 years	2.48	2.55
MRNOHF			
Age:	12 years	2.59**	1.48
	7 years	3.09	2.73
MRNGP			
Age:	12 years	1.85	–
	7 years	3.47	–
GDGP			
Age:	12 years	1.91	2.18
	7 years	3.40**	2.78
MRMOHF			
Age:	12 years	2.94**	1.75
	7 years	1.44	2.35
GDOHF			
Age:	12 years	1.81	2.26**
	7 years	2.95	3.23
COSEOHF			
Age:	12 years	2.02	2.03
	7 years	3.37	3.31
DGDGP			
Age:	12 years	–	2.54
	7 years	–	2.78
DGDOHF			
Age:	12 years	–	–
	7 years	–	2.58
QAFF			
Age:	12 years	2.54	2.36
	7 years	3.51	4.2 **

*6.584 children in the second and sixth years of elementary school were surveyed (averaging 7 and 12 years of age)

**These comparisons between caries scores of children drinking fluoridated and non-fluoridated water show a statistically significant difference regions are located in a natural fluoride belt which runs through the state and the water concentrations were at or above optimal levels for cariostatic action. The remaining regions had sixth grade children with intermediate caries scores.

Among second grade children drinking fluoridated water, the caries scores do not follow the expected pattern (Figure 2D). Though all groups used water with optimal fluoride concentration, there was a wide range in caries scores, and significant differences were measured between geochemical regions. The children of the QAFF, COSEOHF and GDOHF regions had the highest scores while the lowest were in the MRMOHF.

As can be seen in Table 2 and in Figures 1A, 1B, 1C, 1D, there are a wide range of values for caries scores, some at significant levels. Both the sample groups, those drinking fluoridated and nonfluoridated water, varied among the six geochemical regions. Taken overall, there was no significant difference between the means for children drinking fluoridated water compared to those drinking nonfluoridated water. Significant differences, however, were shown between groups within regions. The twelve year olds of MRNOHF and MRMOHF regions who were drinking fluoridated water had significantly lower caries scores, but, in the GDOHF region, there was a higher score in the fluoridated water group. The data from the seven year old children showed equally perplexing results. In the GDGP region the fluoridated group had lower scores, 2.78 vs. 3.40, while in the QAFF group the mean caries score was higher among the children drinking fluoridated water (2.4 vs. 3.51).

These unanticipated results from comparisons of groups of children drinking fluoridated water with those drinking nonfluoridated water caused us to look more closely at caries epidemiology and possible geochemical influences. Because of the multifactoral etiology and the potential for numerous interactions between fluorides and other geochemical factors, it is reasonable to consider other microelements in caries surveys. The concentrations of these elements, which are derived from parent soils and underlying geologic strata, are likely to be stable for long periods of time with the consequence that the dental health of earlier populations should be distributed in a pattern similar to contemporary groups. In order to test this proposition we examined prehistoric skeletal remains of native Americans.

Prehistoric Inhabitants of Missouri

The mid-continental region of North America provided a suitable environment to sustain prehistoric human populations from the earliest periods of human occupation of the continent. Populations became more sedentary and increased markedly with the introduction of agriculture primarily based on the cultivation of maize. These early agriculturalists settled in many localities of Missouri especially during the cultural periods called the Woodland (400–900 AD) and the Mississippian (900–1500 AD). Many archaeological remains have been recovered from their occupation sites together with a significant number of skeletal remains. We surveyed those skeletal collections housed at the Division of American Archaeology, University of Missouri and selected a sample suitable for study of dental disease. From 620 skeletons, we were able to select 179 individuals who were judged complete enough to fulfill our criteria: one or more dental quadrants present, sufficient skeletal material to enable sex and age determination, and the archaeological information needed to establish the provenience of the individual; that is, locality and cultural period were known. A representative sample was obtained for six geochemical regions (see Table 3.)

Standard anthropometric methods were used to establish age and sex. In addition, since the teeth were generally well worn, the degree of tooth wear was also used as an aging criteria. Our results were compared to those on file at the Museum. Where discrepancies occurred, individuals were re-evaluated until an agreement could be reached, or they were rejected. Dental diseases were then recorded.

Table 3. Prehistoric Inhabitants of Missouri

Geochemical Region	Number of Indiv.	# w/coronal caries	% w/coronal caries	# w/root caries	% w/root caries	Total w/all caries	% w/all caries
MRNOHF	16	9	56	4	25	13	81
QAFF	53	28	53	19	36	47	88
MRMOHF	13	1	8	1	8	2	15
PENNOHF	29	1	3	0	0	1	3
GDOHF	50	1	2	0	0	1	2
COSECG	11	0	0	1	9	1	9

First, the presence and type of dental caries (coronal or root) was listed for each tooth. Then measurements were made to record the degree of alveolar bone loss. Six measurements were made around each tooth at the mesial-facial, distal-facial, mesial-lingual, and distal-lingual and at the mid points of the facial and lingual surfaces. On dry bone, it is possible to accurately measure from these points along the alveolar crest to the cemento-enamel junction. Consideration was given to the possibilities of post mortum alveolar bone, fractures and bone lost due to pulpal pathology was recorded but was not added to measurements of bone lost due to periodontal disease.

The caries frequencies are listed in Table 3, which identifies numbers and percents of individuals with coronal or root caries. The highest incidences of coronal caries were for the groups of the MRNOHF and QAFF regions. The same applied to the frequency of root caries. The other four regions had negligible caries frequencies of either type. This geographic distribution is displayed in the computer enhanced plot in Figure 3C. There are significant differences between the high and low caries regions. There is no difference in fluoride concentrations of surface waters of the different regions today which suggests a similar condition several centuries ago. If this is a correct assumption, then the influence of naturally occurring fluorides can probably be ruled out, and the variations in caries rates may be due to differences in other geochemical components of the water and soils.

The MRNOHF is a region of secondary deposits of glacial loess and alluvium from the Missouri and Platt Rivers. The other high caries area, the QAFF, is part of the Mississippian embayment which was an extensive swampy region in prehistoric times. These soils were developed from alluvial deposits of the Mississippi River and are estimated to be of the late Wisconsin glacial age (Feder 1979). These two localities are the same regions where high caries scores were found for both the second and sixth grade children (compare Figures 2 and 3). Thus, the geochemical components that influenced the dental health of prehistoric Americans may also be effecting populations today. In those regions in which school children had high caries rates and the prehistoric populations had low rates, the difference appears to be due to the sources of the water supply; the prehistoric inhabitants took their water from surface sources whereas contemporary inhabitants use deep wells, tapping water from lower geologic strata. The result is that while children in the COSECG region had moderately high caries rates the prehistoric populations benefited from the highly leached soils and had no caries, likewise for the PENNOHF.

Regional differences were also seen in the expression of periodontal disease among prehistoric inhabitants. The measurements of alveolar bone loss were plotted against age for all individuals in this study. These regression lines are shown in Figure 3D. All regressions were significant except for COSECG. That is, periodontal bone loss increased with age as is to be expected because of experience with modern populations. The rate of loss, howver, varied significantly between regions. The lowest incidence of alveolar bone loss, that is the lowest rate of change with age, was among those populations who had lived in the MRNOHF and the highest rate was among populations in the QAFF region. The reader should note that these are the two regions with the highest caries frequencies. Whatever was influencing caries in these two regions did not affect alveolar bone loss in the same way.

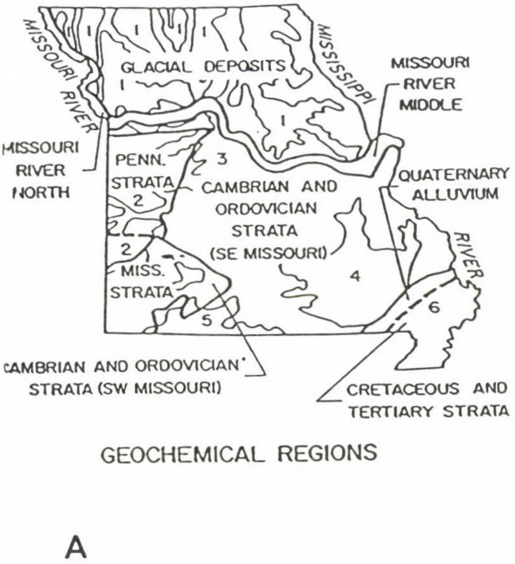

Figure 3A. Geochemical Regions of Missouri

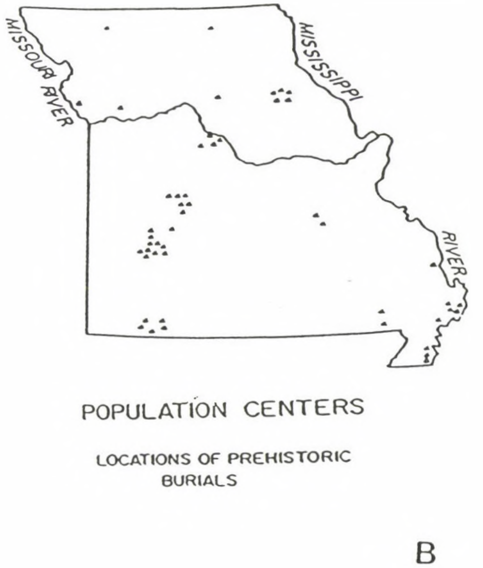

Figure 3B. Population Centers of Prehistoric Burials

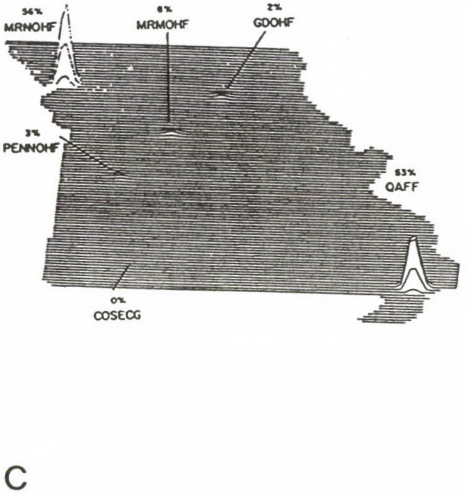

Figure 3C. Computer Plot of Caries Frequencies In Several Prehistoric Populations

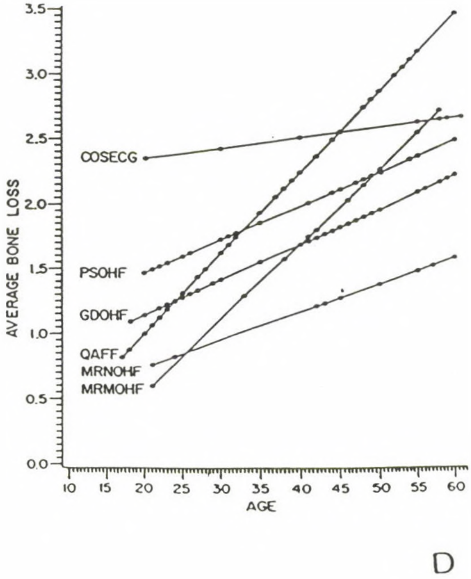

Figure 3D. Average Alveolar Bone With Age

The results of these preliminary investigations of the prehistoric inhabitants and the school children suggest a strong geochemical influence on dental health. Despite vast dietary differences and obvious contrasts in living conditions between ancient and modern populations the two groups show a remarkably similar geographic distribution of dental caries. As a further verification of geographic diversity of dental disease, we began a study of skeletal remains from Hungary.

Earlier Inhabitants of Hungary

Hungary was selected as a region for comparative study for several reasons. First, it has approximately the same area as Missouri and is traversed by two major rivers the Tisza and Duna. Second, Hungary has a diversity of water and soil chemical components (see Pais, 1985; Gerei and Zentay, 1985). Further, the geological strata suggests these conditions have existed over a long time period. The large areas of alluvial and loess deposits also compare to the Missouri conditions. Third, and most important, there is a vast number of skeletons; over 25.000 individuals is one estimate. Mainly, these represent populations from the Neolithic (about 6.000 years ago) through the fourteenth century. These materials are well documented and several reports have been published. These quantities of skeletons are from sites in most areas of Hungary and provide a larger more representative sample of ancient populations than the samples from Missouri which were fewer in number and more widely dispersed geographically. This larger available sample size plus these other features make Hungary a highly useful region for the study of geochemical influence on dental disease and skeletal pathologies in general.

In a previous report one of us (S.M.) described the occurrence and distribution of dental diseases among prehistoric populations from the Neolithic, Copper and Bronze ages (Molnar and Molnar 1985). The results showed a definite contrast in frequencies and types of dental caries and periodontal disease between the earlier and later cultural periods. A geographical variation was suggested by the distribution of features of enamel quality and by type of root caries, but the sample size was too small to test this possibility. We continued our research to expand our data base in the spring and early summer, 1986. Though it is too early to have completely analyzed the data, we do have some preliminary results which we offer as part of this symposium presentation.

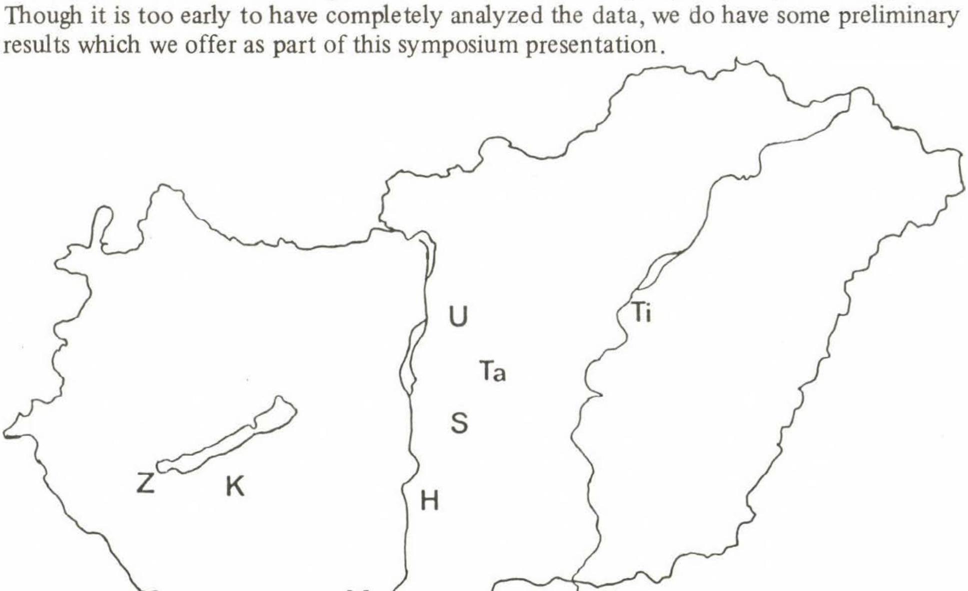

Figure 4. Hungarian Archaeological Site Location

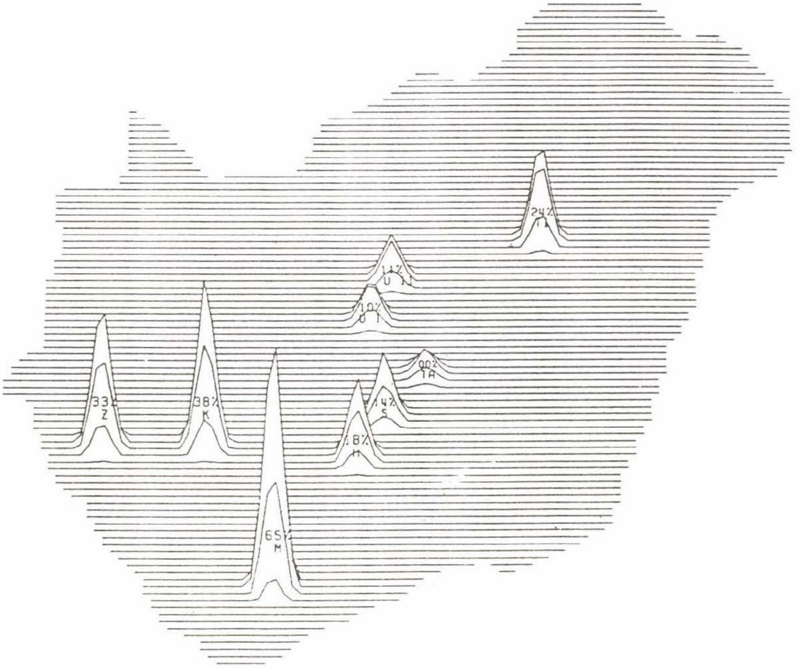

Figure 5. Percentages of Prehistoric Inhabitants of Hungary With Coronal Caries

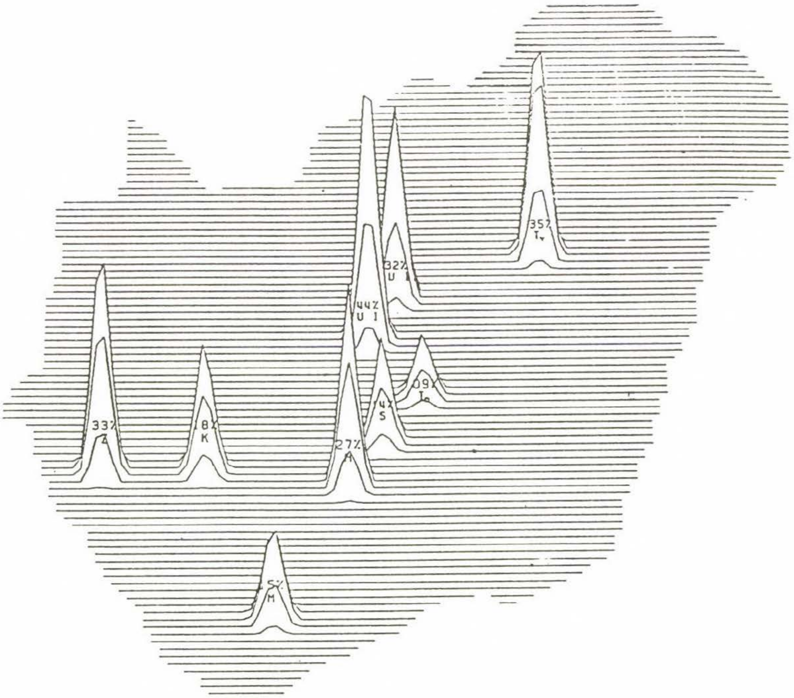

Figure 6. Precentages of Prehistoric Inhabitants of Hungary With Root Caries

Table 4. Earlier Inhabitants of Hungary, and approximate dates of archaeological sites

Location	Number of Indiv.	# w/coronal caries	% coronal caries	# w/root caries	% w/root caries	#w/root ϵ coronal caries	Total w/all caries	% w/all caries	Approximate date of archaeological sites
Üllő I	39	3	8	17	44	2	22	56	Avar Period, 600 AD
Üllő II	30	2	7	8	27	1	11	37	Avar Period, 700 AD
Tatárszentgyörgy	14	0	0	1	7	0	1	7	Avar Period, 600 AD
Szabadszállás	22	3	14	2	9	2	7	32	Avar Period, 500 AD
Homokmégy	23	3	13	6	26	1	10	43	Avar Period, 700 AD
Mohács	20	11	55	1	5	2	13	65	Avar Period, 1300 AD
Kér-Puszta	34	12	35	2	9	3	18	53	Arapad Period, 1000 AD
Zalavár	31	7	23	7	23	2	16	52	Arapad Period, 900 AD
Tiszaderzs	17	5	29	5	29	2	12	71	Avar Period, 600 AD

We examined over twenty collections of skeletal remains recovered from sites distributed over the nation and selected those which were well preserved and were representative of diverse soil conditions. The nine localities of the collections which are described in this report are the remains of populations from the sixth century, Avar period, to a 1300 A. D. cemetary in Mohács (see Table 4). Mohács, Homokmégy, Zalavár and Tiszaderzs are localities of either deep alluvial deposits or swampy regions and were subject to periodic flooding. Szabadszállás is in an alkali type of soil of low flood plains and Tatárszentgyörgy is a sandy chernozem. The Üllő sites are located on a boggy peat meadow soil while Kér-puszta is a brown-forest type (Map, Figure 4.) More detailed geochemical data are available for each of these sites. A fuller description will appear later as will the results of statistical testing which is just beginning. A few interesting contrasts, however, can be pointed out.

The greatest differences are those between the caries types. For example, 55% of the skulls from Mohács have coronal caries, while only one of the twenty (5%) has root caries. Üllő I and Üllő II have high percentages of skulls with root caries but only a few with coronal caries (see Table 4 and Figures 5 and 6). The Tiszaderzs collection has 71% of the skulls with one or both types of caries, followed by 65% from Mohács. A clear geographic distribution is seen for coronal caries frequencies; those localities from alluvial or swampy regions have the highest. Kér-puszta is included in this group with high coronal caries but the locality is a different geographic region with a different soil classification. The sandy or alkali soil localities of Szabadszállás and Tatárszengyörgy are the lowest in caries frequencies when all types of caries are considered. As of yet we have not been able to determine any clear geographical distribution for root caries.

Dietary differences are likely to confound the results to some degree, as is to be expected; yet geographical trends for specific time periods are clearly evident. Of note, is that the most recent localities, Kér-puszta and Mohács, have the highest incidences of coronal caries but the lowest incidences of root caries. The greater use of finely ground grains during these times may contribute to the high incidences of coronal caries. As of yet, we are unable to offer a possible explanation for the low incidences of root caries. A possibility is that the micro-organisms causing root caries are different species and are influenced by oral environments which contrast to those affecting the *Streptococcus mutans,* the organism causing coronal caires (see Katz 1980).

Conclusions

We have conducted a series of interrelated preliminary studies of populations who are geographically widely dispersed and who have lived during a variety of time periods. Our sample sizes are adequately large to allow some inferences to be made:

1. Geochemical factors derived from young parent geological materials appear to affect dental health.
2. Affects of geochemical factors associated with young parent materials appear to be most pronounced in low swampy areas located in alluvial plains.
3. Geochemical factors may interfer with the caries protective effects of fluorides.
4. Periodontal disease, coronal caries, and root caries appear to be affected by different geochemical factors.

Statistical tests are now underway which should enable us to make inferences as to which geochemical factors are most likely affecting dental health. We also intend to collect more data on dental health and disease from extant and extinct populations in Missouri and Hungary.

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