Interrelations between drainage basin variables using Correspondance Analysis

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Summary

Searching for the intenelations between drainage basin variables we used Correspondance analysis.Using this techique from a two dimensional matrix with 37 columns representing various morphometric variables we tried to extract the maximum of information.

The visual inspection of the resulting graph of simultaneous representation of smples and variables is instrumental in showing us the relationship between variables and individuals.

It is certain that the degree to which fluvial variables interact depends on various factors such as structure,lithology downwasting processes and the stage of basin development.It can be concluded that the correlation between the morphometric elements has a trend to increase from low to high stream orders.

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ΠΕΡΙΛΗΨΗ

Στην παρούσα εργασία μελετάται η σχέση των μεταβλητών μιας υδρογραφικής λεκάνης χρησιμοποιώντας τη μέθοδο της Correspondance Analysis. 'Ετσι, ξεκινώντας με ένα πίνακα δύο διαστάσεων που έχει 37 στήλες που αντιπροσωπεύουν διάφορες μορφομετρικές μεταβλητές προσπαθούμε να εξάγουμε το μέγιστο των πληροφοριών από αυτά τα δεδομένα. Η προκύπτουσα γραφική παράσταση δείχνει τις "σχέσεις" μεταξύ των υπό μελέτη μεταβλητών και των υπο-λεκανών του συστήματος. Είναι προφανές, οι σχέσεις των διαφόρων μεταβλητών μιας υδρογραφικής λεκάνης εξαρτώνται από ποικίλους παράγοντες, όπως η δομή, η λιθολογία, οι διαδικασίες διάστρωσης, το στάδιο εξέλιξης κ.λ.π. Συμπεραίνεται ότι η μεγαλύτερη συσχέτιση των μορφομετρικών μεταβλητών παρατηρείται σε υπολεκάνες μεγαλύτερης τάξεως.

INTRODUCTION

Correspondance analysis is a relatively new multivariate statistical method developed by Benzecri (1973). We have already emphasized the use of this method in geomorphological data (Gournellos and Karakos, 1989).

In this paper we try to search for the interrelations between different variables of a drainage basin. The data come from the Vouraikos basin of North Peloponese (Gournellos and Stasinoulias unpublished work).

In the analysis we have used the program Praxitele developed at the University of Thrace (Karakos 1988). The program calculates the Eigenvalues (TABLE 1) and it computes for each sample and each variable their contributions and the cosinus of their angle with their resulting factors (TABLES 2,3).

Interrelations between drainage basin variables

We have used a two dimensional array of 9 colúmns representing sub-basins of a drainage system and 37 rows representing morphometric variables such as, areas, perimeters, lengths, numbers of streams, e.t.c. The advantages of correspondance analysis are the use of continuous and discontinuous variables, and the simultaneous representation of samples and variables (Figure 1). Continuous variables have been transformed to discrete variables by dividing the ranges of continuous data into a proper number of discrete pieces. We have used lithology as our discontinuous variable.

The interpretation of the Graph (Figure 1) must be based on the fact that the points of variables will show their mutual correlations, and also the different clusters of samples will suggest a "genetic" relationship. It is important to remember that we represent in two-dimensional space, two multi-dimensional spaces (samples and variables) and so it is necessary also to consider the angle (cosinus) of each variable (or sample) in relation to its factor.

Our attempt was to have the best possible projection of the variables and sample points. The program easily enables the definition of some supplementary variables which are not included in the analysis but which way have their projections on the Graph. These supplementary variables are in Table 3B. The variables which really participate and contribute to axes formation are those in Table 3A. Figure 1 depicts the projections of variables and sample points on the first and second factorial axes. The percentage of inertia in these axes is 59,6% which means a good representation of the original variables. Following a visual inspection of Figure 1 and using the data of Tables 2, 3A and 3B we can conclude:

1. There are two distinct groups of point samples X_4, X_8, X_9 and X_1, X_3, X_5, X_6 each of them having high contribution to factor 1 and 2 respectively.
   Between these groups there is a third with high contribution to the second and third axes.

2. There are several groups of variables:

   a. The linear variables such as stream lengths ($L_1, L_2, \ldots$) and perimeters which are quite well correlated. In particular there is a good correlation between L_1, L_2, L_4, L_8.

   b. The areal variables such as areas (A_1, A_4) drainage densities (D_d, D_e) and drainage frequences (F_s, F_e), where A_4, D_d and F_s also have a good correlation.

c. The relief variables like relief ratio (R_h) basin relative relief (R_{hp}), main channel fall (MCF), average ground slope (Θ_g), mean stream channel slope (Θ_c) and Ruggedness number (R_n) are also sometimes well correlated.

d. It seems that very good correlation exists between basin--form variables like basin length (BL), basin elosgation (BE) and form factor (FF).

e. There are some variables belonging to the same groups which are uncorrelated with the others, like areas of first order (A_1), number of streams (N_3), average stream length (L_1, L_{int}), basin width (BW) e.t.c.

3. The above-mentioned groups of variables also have a close relationship as for example:
Linear variables (ΣL, L_2, L_{L1}, L_e, L_3) with areal variables (A_4, D_d, F_s) and relief variables (MCF, R_{hp}).

4. Due to the complicated interrelations between the various morphometric variables there is no quich and easy interpretation of the results.

Figure 1

It is a projection of all samples and variables on to first and second factorial axes. The samples represent 9 sub-basins of fourth order. The Underlined variables represent principal variables (TABLE 3A).

The variables are:

1) Stream numbers (N_e, N_2, N_3, Σ_N) and bifurcation ratios (Rb).
2) Stream lengths (L_e, L_2, L_3, L_N, Σ_L, L_e, L_2, L_3) the link-length ratio (LLR) and stream length ratio (SLR).
3) The basin size variables such as area (A_1, A), perimeter (P), basin length (BL), basin circularity ratio (BCR), basin average width (BAW), basin elongation (BE) and form factor (FF).
4) The texture of dissection variables such as: density of Links (D_e, D_2, D_3, D_d), frequency of Links (F_e, F_2, F_3, F_s) and the drainage texture ratio (DTR).
5) The relief variables like: relief ratio (R_h), basin relative relative relief (R_{hp}), main channel fall (MCF), the average ground slope (θ_g), the mean stream channel slope (θ_c), the Ruggeduess number (R_n) and
6) The lithology (R_0).

PREMIERE VALEUR PROPRE (TRIVIALE)

A/A	VAL PROP	%	CUMUL
2	0.40472952	40.473	40.473
3	0.19135226	19.135	59.608
4	0.15082563	15.083	74.691
5	0.10190776	10.191	84.882
6	0.07670007	7.670	92.552
7	0.03406861	3.407	95.958
8	0.02847387	2.847	98.806
9	0.01194258	1.194	100.000

TABLE 1

CONCLUSION

The wide-spread use of computers make very complicate mathematical problems seem trivial. Multivariated statistica methods are sometimes very useful in studing the interrelatior between a number of variables in Physical Geography and Geology On the basin of Correspondance analysis we can combined th advantages of R- and Q- mode analysis while simultaneusl observing the results.

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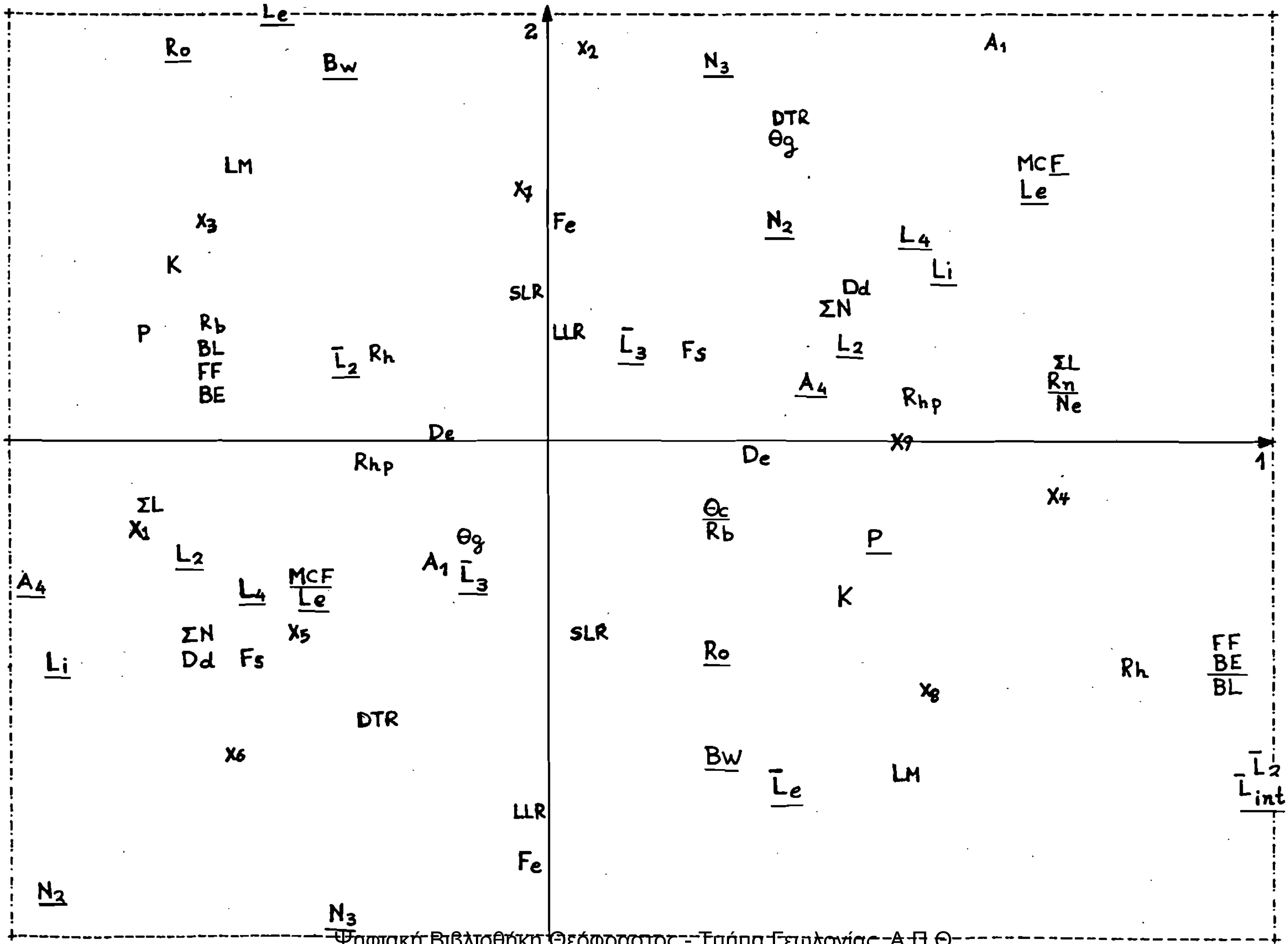

Le
Ro
Bw
2
X2
N3
A1
DTR
Θg
MCF
Le
LM
X7
X3
Fe
N2
L4
Li
K
SLR
Dd
ΣN
P
Rb
BL
FF
BE
L2
Rh
LLR
L3
Fs
L2
A4
Rhp
ΣL
Rn
Ne
De
Rhp
X9
De
1
X4
ΣL
X1
Θc
Rb
P
L2
Θg
A4
A1
L3
L4
MCF
Le
K
ΣN
X5
SLR
Dd
Fs
Ro
FF
BE
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Rh
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X8
DTR
X6
Bw
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L2
Lint
LLR
Fe
N2
N3

A/A	I1	GLT	POID	INR	1"FACT	COS	CTR	2"FACT	COS	CTR	3"FACT	COS	CTR	4"FACT	COS	CTR	5"FACT	COS	CTR	6"FACT	COS	CTR
1	X_1	925	111	106	-763	609	160	-155	25	14	451	213	150	109	13	13	21	0	1	249	65	203
2	X_2	989	111	109	68	5	1	752	578	328	430	189	136	336	115	123	-245	62	87	-199	40	129
3	X_3	920	111	104	-633	429	110	411	181	98	163	29	20	-355	135	138	355	135	183	102	11	34
4	X_4	947	111	137	1030	861	291	-96	8	5	286	66	60	-42	1	2	61	3	5	-96	8	30
5	X_5	930	111	89	-458	260	58	-364	165	77	-284	100	59	175	38	33	-536	357	417	88	10	25
6	X_6	998	111	109	-607	376	101	-609	379	215	-127	17	12	118	14	15	281	81	114	-357	131	416
7	X_7	960	111	105	-60	4	1	478	242	133	-702	522	363	-404	173	178	-119	15	20	-59	4	11
8	X_8	963	111	123	751	511	155	-469	199	128	243	54	44	-445	179	216	-135	16	26	67	4	15
9	X_9	995	111	119	671	420	123	53	3	2	-461	198	156	509	241	282	318	94	147	205	39	137
TOTAL =		180.0		1000			1000			1000			1000			1000			1000			1000

TABLE 2

	A/A	V2	QLT	POID	INR	1"FACT	COS	CTR	2"FACT	COS	CTR	3"FACT	COS	CTR	4"FACT	COS	CTR	5"FACT	COS	CTR	6"FACT	COS	CTR
	1	ZZ7	786	28	22	593	440	0	297	110	0	341	145	0	1	0	0	256	82	0	86	9	0
ΣN	2	ZZ8	786	22	28	-742	440	0	-371	110	0	-426	145	0	-1	0	0	-319	82	0	-107	9	0
	3	ZZ9	996	33	17	340	232	0	-107	23	0	286	163	0	335	224	0	-311	193	0	284	161	0
Rb	4	Z10	996	17	33	-681	232	0	214	23	0	-571	163	0	-670	224	0	622	193	0	-567	161	0
	5	Z21	946	22	28	990	784	0	136	15	0	321	83	0	280	63	0	-1	0	0	-31	1	0
ΣL	6	Z22	946	28	22	-792	784	0	-109	15	0	-257	83	0	-224	63	0	1	0	0	25	1	0
	7	Z31	675	39	11	3	0	0	204	146	0	-255	228	0	150	79	0	59	12	0	-245	210	0
LLR	8	Z32	675	11	39	-9	0	0	-714	146	0	894	228	0	-526	79	0	-206	12	0	856	210	0
	9	Z33	566	22	28	72	4	0	-351	99	0	-117	11	0	-136	15	0	739	437	0	22	0	0
SLR	10	Z34	566	28	22	-57	4	0	281	99	0	93	11	0	109	15	0	-592	437	0	-18	0	0
	11	Z41	890	11	39	863	213	0	749	160	0	922	243	0	460	60	0	-333	32	0	-798	182	0
A_1	12	Z42	890	39	11	-247	213	0	-214	160	0	-263	243	0	-131	60	0	95	32	0	228	182	0
	13	Z45	996	33	17	-642	825	0	195	76	0	-29	2	0	-11	0	0	-147	43	0	-158	50	0
BE	14	Z46	996	17	33	1285	825	0	-391	76	0	59	2	0	22	0	0	294	43	0	317	50	0
	15	Z47	996	33	17	-642	825	0	195	76	0	-29	2	0	-11	0	0	-147	43	0	-158	50	0
FF	16	Z48	996	17	33	1285	825	0	-391	76	0	59	2	0	22	0	0	294	43	0	317	50	0
	17	Z49	920	28	22	561	394	0	-294	108	0	-392	192	0	-166	34	0	293	107	0	-261	85	0
K	18	Z50	920	22	28	-701	394	0	368	108	0	489	192	0	207	34	0	-366	107	0	326	85	0
	19	Z51	571	17	33	414	86	0	-4	0	0	-46	1	0	-305	46	0	648	210	0	675	228	0
De	20	Z52	571	33	17	-207	86	0	2	0	0	23	1	0	152	46	0	-324	210	0	-337	228	0
	21	Z53	786	28	22	593	440	0	297	110	0	341	145	0	1	0	0	256	82	0	86	9	0
Dd	22	Z54	786	22	28	-742	440	0	371	110	0	-426	145	0	-1	0	0	-319	82	0	-107	9	0
	23	Z55	618	33	17	9	0	0	407	332	0	54	6	0	-131	34	0	117	28	0	330	218	0
Fe	24	Z56	618	17	33	-18	0	0	-815	332	0	-108	6	0	262	34	0	-235	28	0	-660	218	0
	25	Z57	986	33	17	295	174	0	188	71	0	478	456	0	58	7	0	225	102	0	297	176	0
Fs	26	Z58	986	17	33	-589	174	0	-377	71	0	-955	456	0	-116	7	0	-451	102	0	-593	176	0
	27	Z59	798	22	28	446	159	0	640	327	0	270	58	0	350	98	0	441	156	0	17	0	0
DTR	28	Z60	798	28	22	-357	159	0	-512	327	0	-216	58	0	-280	98	0	-353	156	0	-13	0	0
	29	Z61	633	39	11	-319	357	0	136	65	0	80	22	0	-28	3	0	-95	31	0	-210	155	0
Rh	30	Z62	633	11	39	1118	357	0	-476	65	0	-280	22	0	100	3	0	331	31	0	736	155	0
	31	Z63	707	33	17	-357	255	0	-23	1	0	394	311	0	178	63	0	-39	3	0	-192	74	0
Rhp	32	Z64	707	17	33	714	255	0	47	1	0	-789	311	0	-356	63	0	78	3	0	384	74	0
	33	Z67	946	22	28	990	784	0	136	15	0	321	83	0	280	63	0	-1	0	0	-31	1	0
Rn	34	Z68	946	28	22	-792	784	0	-109	15	0	-257	83	0	-224	63	0	1	0	0	25	1	0
TOTAL =				180.0	850			738			453			713			388			1018			2361

TABLE 3B

	A/A	V2	QLT	POID	INR	1"FACT	COS	CTR	2"FACT	COS	CTR	3"FACT	COS	CTR	4"FACT	COS	CTR	5"FACT	COS	CTR	6"FACT	COS	CTR
	1	ZZ1	946	22	28	990	784	54	136	15	2	321	83	15	280	63	17	-1	0	0	-31	1	1
N_e	2	ZZ2	946	28	22	-792	784	43	-109	15	2	-257	83	12	-224	63	14	1	0	0	25	1	1
	3	ZZ3	957	33	17	479	458	19	430	369	32	-17	1	0	-210	88	14	141	40	9	18	1	0
N_L	4	ZZ4	957	17	33	-957	458	38	-860	369	64	34	1	0	420	88	29	-283	40	17	-36	1	1
	5	ZZ5	930	28	22	338	143	8	730	667	77	-146	27	4	27	1	0	267	89	26	-51	3	2
N_3	6	ZZ6	930	22	28	-423	143	10	-913	667	97	182	27	5	-33	1	0	-334	89	32	63	3	3
	7	Z11	975	17	33	927	429	35	539	145	25	219	24	5	837	351	115	161	13	6	-162	13	13
L_e	8	Z12	975	33	17	-463	429	18	-270	145	13	-110	24	3	-419	351	57	-80	13	3	81	13	6
	9	Z13	916	28	22	773	748	41	328	134	16	-104	14	2	-30	1	0	-87	9	3	-89	10	6
L_1	10	Z14	916	22	28	-967	748	51	-410	134	19	130	14	3	37	1	0	108	9	3	111	10	8
	11	Z15	979	28	22	553	382	21	172	37	4	-242	73	11	-462	267	58	347	150	44	237	70	46
L_2	12	Z16	979	22	28	-691	382	26	-215	37	5	302	73	13	578	267	73	-434	150	54	-296	70	57
	13	Z17	931	22	28	703	396	27	380	115	17	166	22	4	-435	152	41	-395	125	45	-389	121	99
L_3	14	Z18	931	28	22	-562	396	22	-304	115	13	-133	22	3	348	152	33	316	125	36	311	121	79
	15	Z19	990	22	28	725	421	29	-641	329	48	-38	1	0	109	10	3	474	180	65	-246	49	40
LM	16	Z20	990	28	22	-580	421	23	513	329	38	30	1	0	-87	10	2	-379	180	52	197	49	32
	17	Z23	916	28	22	436	238	13	-679	577	67	-177	39	6	197	49	11	-8	0	0	-102	13	8
L_e	18	Z24	916	22	28	-545	238	16	849	577	84	221	39	7	-246	49	13	10	0	0	127	13	11
	19	Z25	985	11	39	1400	560	54	-647	119	24	681	133	34	-763	166	63	-133	5	3	-80	2	2
L_n	20	Z26	985	39	11	-400	560	15	185	119	7	-195	133	10	218	166	18	38	5	1	23	2	1
	21	Z27	985	11	39	1400	560	54	-647	119	24	681	133	34	-763	166	63	-133	5	3	-80	2	2
L_2	22	Z28	985	39	11	-400	560	15	185	119	7	-195	133	10	218	166	18	38	5	1	23	2	1
	23	Z29	999	28	22	143	25	1	202	51	6	810	821	121	-249	78	17	41	2	1	134	22	15
L_3	24	Z30	999	22	28	-178	25	2	-253	51	7	-1013	821	151	311	78	21	-51	2	1	-167	22	18
	25	Z35	996	17	33	1285	825	68	-391	76	13	59	2	0	22	0	0	294	43	19	317	50	19
BL	26	Z36	996	33	17	-642	825	34	195	76	7	-29	2	0	-11	0	0	-147	43	9	-158	50	25
	27	Z37	853	22	28	-425	145	10	730	426	62	-252	51	9	-195	30	8	-493	194	70	-91	7	5
BAW	28	Z38	853	28	22	340	145	8	-584	426	49	202	51	8	156	30	7	394	194	56	73	7	4
	29	Z39	975	28	22	608	462	25	-182	42	5	-472	279	41	-130	21	5	-297	110	32	221	61	40
P	30	Z40	975	22	28	-760	462	32	228	42	6	590	279	51	163	21	6	371	110	40	-277	615	50
	31	Z43	994	33	17	524	550	23	134	36	3	-209	87	10	67	9	1	-395	312	68	5	0	0
A	32	Z44	994	17	33	-1049	550	45	-269	36	6	418	87	19	-134	9	3	790	312	136	-10	0	0
	33	Z65	975	17	33	927	429	35	539	145	25	219	24	5	837	351	115	161	13	6	-162	13	13
MCF	34	Z66	975	33	17	-463	429	18	-270	145	13	-110	24	3	-419	351	57	-80	13	3	81	13	6
	35	Z69	901	39	11	-137	66	2	-173	105	6	428	640	47	-47	8	1	-103	37	5	-113	45	15
θ_g	36	Z70	901	11	39	480	66	6	607	105	21	-1496	640	165	163	8	3	359	37	19	395	45	51
	37	Z71	996	33	17	340	232	10	-107	23	2	286	163	18	335	224	37	-311	193	42	284	161	79
θ_c	38	Z72	996	17	33	-681	232	19	214	23	4	-571	163	36	-670	224	73	622	193	84	-567	161	158
	39	Z73	993	17	33	-695	242	20	768	295	51	896	402	89	94	4	1	157	12	5	276	38	37
R_o	40	Z74	993	33	17	348	242	10	-384	295	26	-448	402	44	-47	4	1	-78	12	3	-138	38	19
TOTAL =				180.0	1000			1000			1000			1000			1000			1000			1000

TABLE 3A