Geologische Bundesanstalt

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Application of a handheld X-ray fluorescence analyser to trace the provenance of Roman monuments of Neogene lithotypes to quarries in the Leitha Mountains, Hainburg Mountains and along the south-west border of the Vienna Basin

Short title: APPLYING PORTABLE-XRF ON ROMAN ARCHAEOLOGICAL STONE OBJECTS AND SOURCE ROCKS OF NEOGENE LITHOTYPES FROM GREATER LEITHA AREA

Sumary 1 of 2

For the archaeological-geological project „Stone Monuments and Stone Quarrying in the Carnuntum – Vindobona Area“ (CarVin FWF P 26368-G21, G. Kremer) the method of non-destructive chemical semiquantitative analysis with a handheld XRF was tested on quarry samples and archaeological stone objects of special Upper Miocene lime- and sandstone varieties for proof or clarification of macroscopic assignments within the frame of a lithotype classification and accordingly defined quarry areas within the Southern Vienna and adjacent Pannonian Basin. For project details see https://meetingorganizer.copernicus.org/EGU2018/EGU2018-18923.pdf

However difficult the interpretation of results (compare scatterplots) by this in many ways questionable method is, some conclusions of the attempt can be drawn:

One can more easily distinguish groups starting from the quartz-end member of the sedimentary rocks. These are highly siliceous Flysch sandstones (no. 1 – numbers referring to scatterplots; but this group is outside of project issues), calcite-bearing sandstones from the Sarmatian-Pannonian (no. 2; partly no. 10) and further mixed calcareous-silicious biodetrites (Atzgersdorf, no. 15).

Sumary 2 of 2

The presentation covers mainly the inferred chemical characteristics of the quarry samples, and has not been interpreted here regarding the assignment of the archaeological objects to quarry regions via correspondence with quarry samples.

Within the quarry samples the differences between the carbonaceous and the siliceous lithological compositions emerge. In the carbonaceous regime the following elements are relatively higher: Al, partly Ba, Ca, Mg, partly Mn, P, S and Sr. In the siliceous regime Fe, K, Si and Ti are enriched. As some groups are not uniform and can also represent mixed carbonate-siliciclastic systems, there are either two pools or stronger scattering behaviour (e.g. no. 10 Nußdorf etc., or no. 19 Au-LorettoS). Ba and Mn appear to vary within some groups (Ba enriched in no. 1 Flysch, or Mn enriched in no. 16 Teufelsjoch).

Overall it turned out that there is a striking difference between the pool of the quarry samples and the pool of especially calcareous archaeological objects. One can argue that the rocks behind these pools are not well overlapping. However, there is a clear difference as the latter show higher sulfur contents at the cost of Ca, Mg, Ba, Al and the Balance („LOI“). This may be due to the influence of some kind of surface treatment and environmental effects on the archaeological objects and it certainly regards further questioning if comparison with unweathered rock samples is desired.

Although not elaborated here, the method led to a characterization of lithostratigraphical groups (designed also to fit the relevant quarry areas) at least to some degree, and further on to some possible comparisons between archaeological objects and quarry regions.

Application of XRF Analyser from AnalytiCON Instruments NITON XL3t 900s; Mining Mode Cu/Zn including light elements.
Measurement period 2014-2019.
Only closed dataset due to dependency on instrument-calibration, i.e. measurements comparable only within the dataset.
Interpreted data: about 630 measures of 300 archaeological stone objects and 290 measures of 155 quarry samples.
8 mm diameter window, held on objects' surfaces, where as fesh as possible, and on preferably cut quarry samples; usually 2 (seldom more) analyses per object or sample. A few object drill cores were also available.

The next slides show the compiled geology of the targeted Neogene strata within the investigated area and outline the structure of the defined quarry areas and quarry regions.

project area CarVin

Geological units / Middle - Upper Miocene

Pannonian (& Pontian) 11,6 - 5,3 my

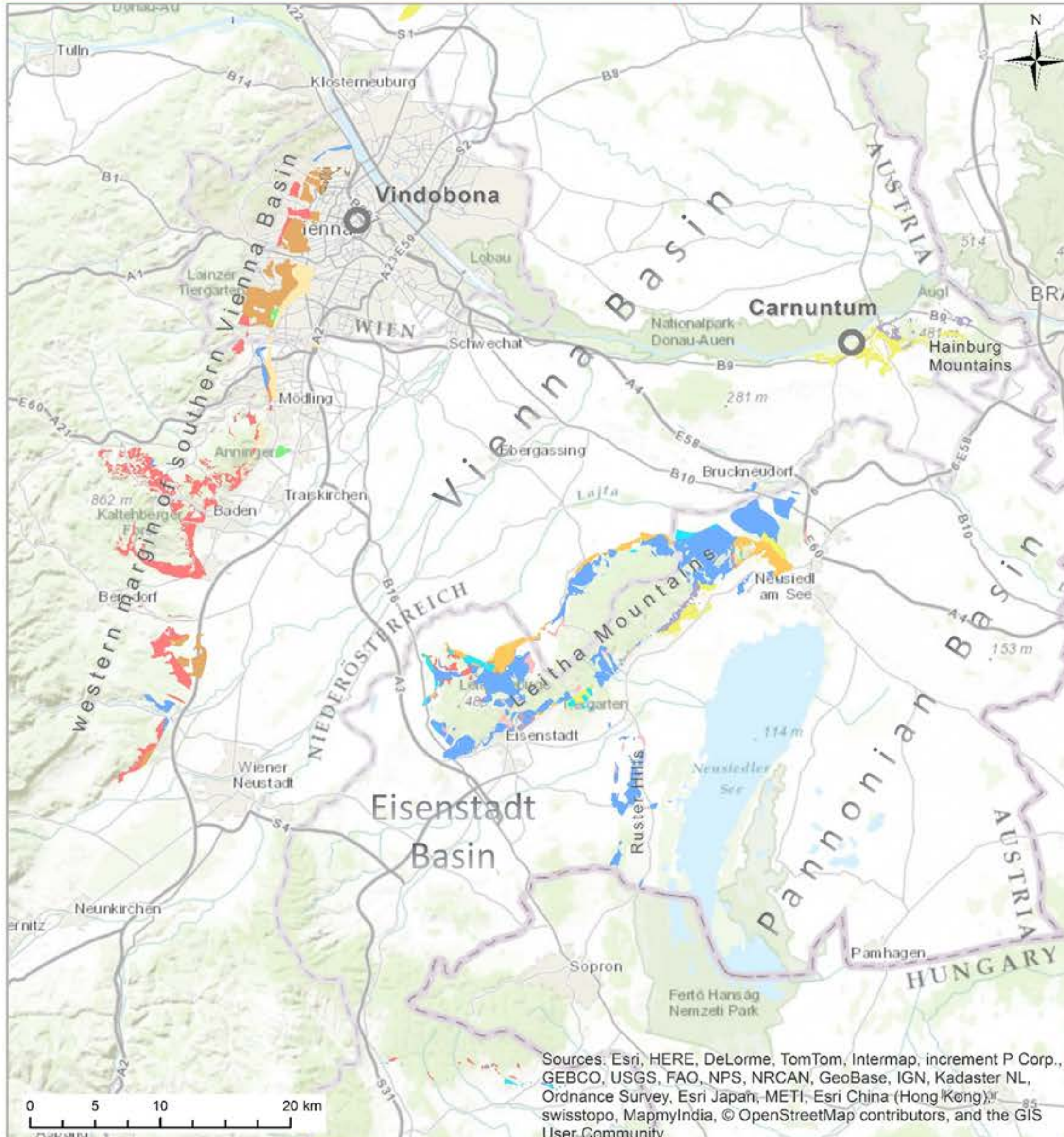
- conglomerate, sand, gravel

Sarmatian 12,8 - 11,6 my

- Atzgersdorfer Kalksandstein
- sand, sandstone
- conglomerate, sand, gravel
- clastic sediments, 'detritärer Leithakalk'
- clayey marl, sand, sandstone
- 'detritärer Leithakalk'

Badenian 16,3 - 12,8 my

- sand, sandstone
- breccia, conglomerate, partly unconsolidated
- 'Leithakalk', clastic sediments
- 'Leithakalk'



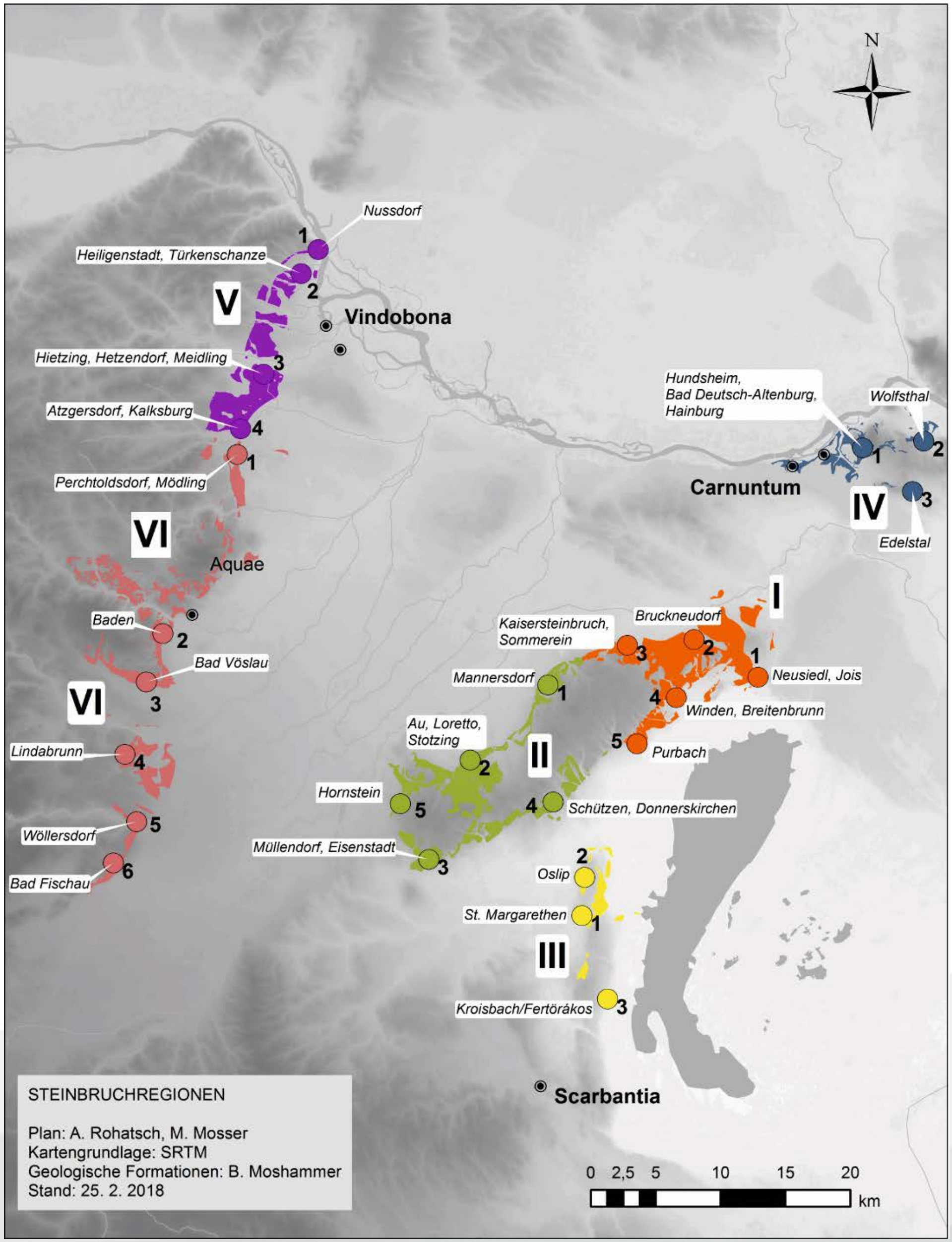
Project area CarVin:

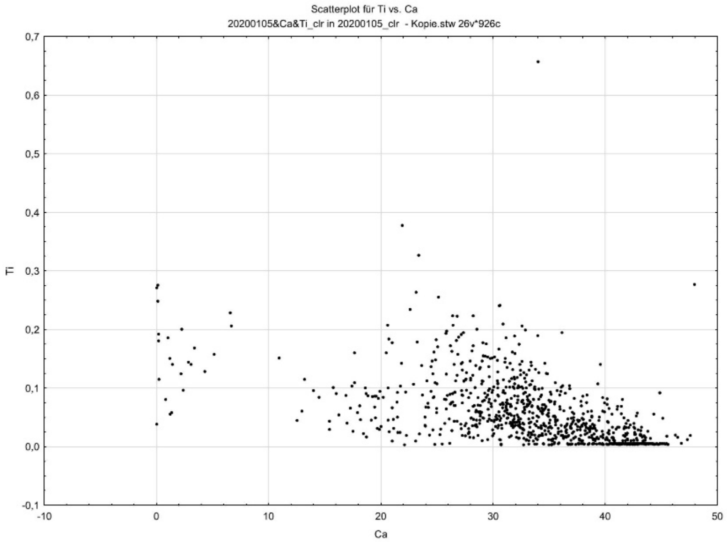
advisedly allocated quarry areas & - regions defined with respect to the Neogene rocks used in Vindobona and Carnuntum and their hinterlands

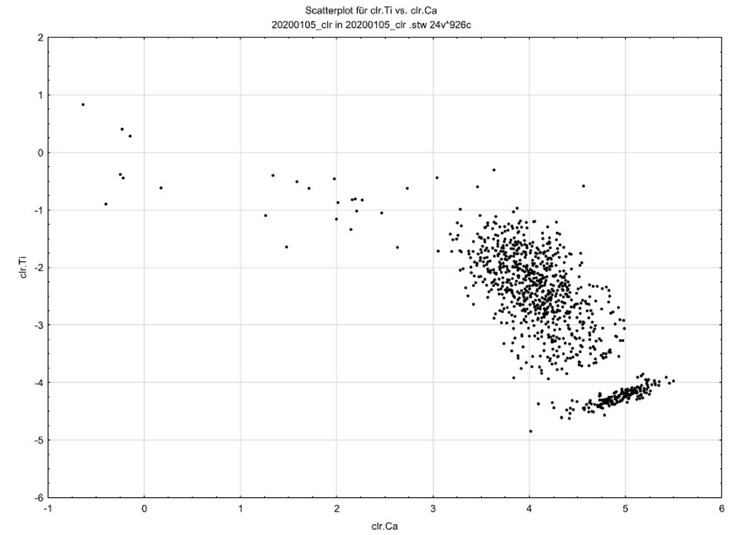
Quarry areas named after villages and towns are grouped into the following **quarry regions,** presented in colour:

Leitha Mountains northeast (I)
Leitha Mountains southwest (II)
Rust – Fertörákos Hills (III)
Hainburg Mountains (IV)
Slopes at Vienna Woods (V)
Slopes at Northern Calcareous Alps (VI)

Numbers from above are used in the legend of the following chemical element scatterplots.
The tailored lithological classification of main categories and lithotypes is described in the EGU-2018 abstract.







The raw data of the analyses are given in percentages. The interpreted chemical elements are Al, Ba, Ca, Cl, Fe, K, Mg, Mn, P, Si, Sr, Ti. Additionally a Balance (Bal) is issued approximating the difference to 100, it comprises elements whose atomic weight is lighter than Mg, hence mainly loss of ignition and humidity.

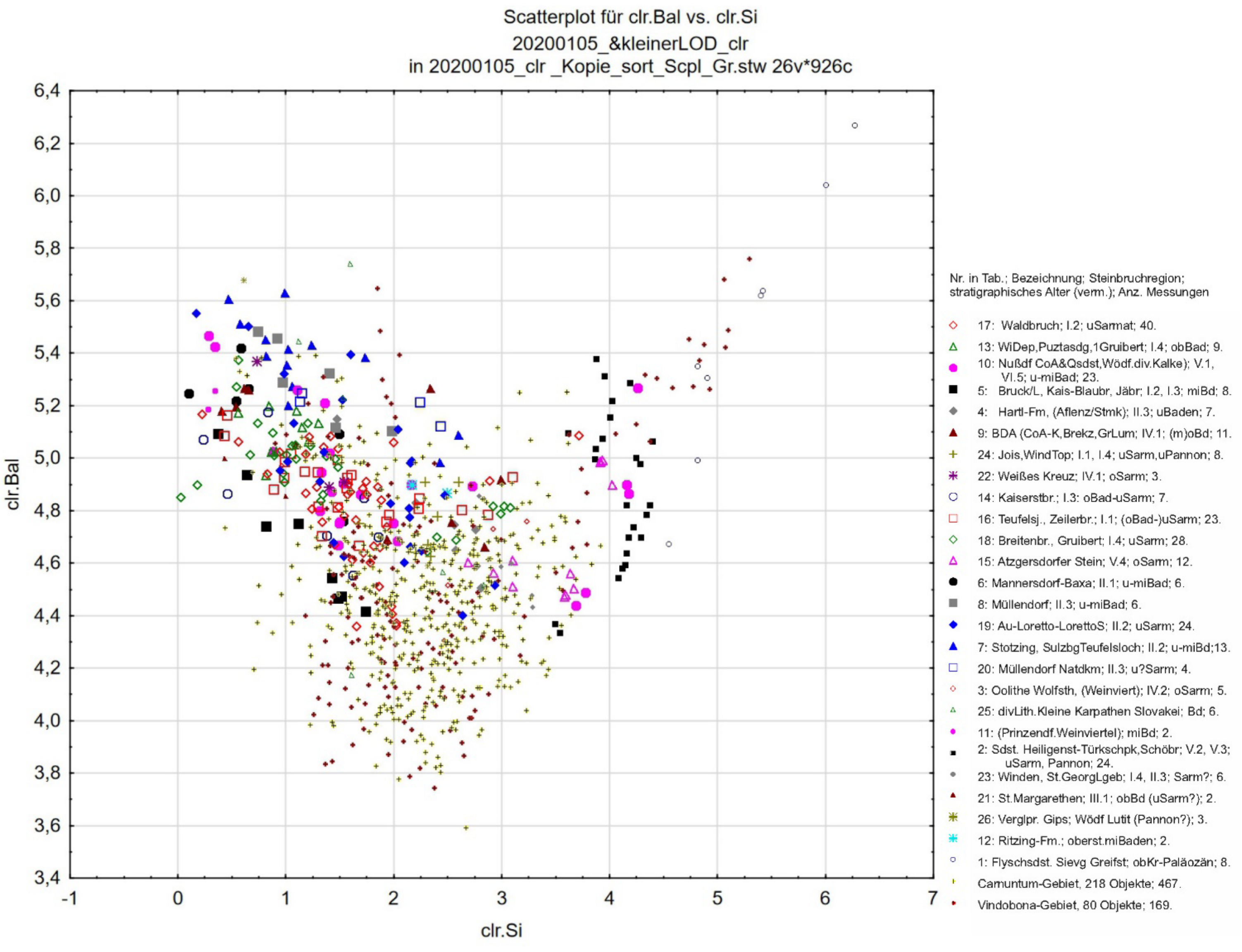
To compare the samples according to their chemical main- and minor-, and even some trace-elements, calculated as percentages, a compositional data analysis is very recommended. The above diagrams show the result: to the left with original data, to the right after their transformation via software CodaPack into centred-log-ratio (clr) coordinates. The clr-data are interpreted on base of scatterplots. Within some elements separate clusters emerged - as in the above example of Ti -, yet testing attributed them as unanimously caused by an original value below detection limit, which was here used as half value.

In the following slides preliminary scatterplots of pairs of chemical elements are prepared, covering 926 measurements:

Balance (‚LOI‘) – Silicon; complete
Balance (‚LOI‘) – Silicon; zoomed
Barium – Strontium; complete
Barium – Strontium; zoomed
Magnesium – Calcium; complete
Magnesium – Calcium; zoomed
Titanium – Manganese; zoomed
Iron – Potassium; zoomed (only without gypsum sample)
Phosphorus – Sulfur; complete
Phosphorus – Sulfur; zoomed

The legend symbols are partly bad transferred: the last two regard the archaeological objects: those in connection with the Carnuntum area are small yellow crosses, those conntected with Vindobona areas are small red crosses.

A further interpretation of these scatterplots with regard to the archaeological objects is under preparation.


Scatterplot für clr.Bal vs. clr.Si
20200105_&kleinerLOD_clr
in 20200105_clr _Kopie_sort_Scpl_Gr.stw 26v*926c
clr.Bal
clr.Si
6,4
6,2
6,0
5,8
5,6
5,4
5,2
5,0
4,8
4,6
4,4
4,2
4,0
3,8
3,6
3,4
-1
0
1
2
3
4
5
6
7
Nr. in Tab.; Bezeichnung; Steinbruchregion; stratigraphisches Alter (verm.); Anz. Messungen
17: Waldbruch; I.2; uSarmat; 40.
13: WiDep,Puztasdg,1Gruibert; I.4; obBad; 9.
10: Nußdf CoA&Qsdst,Wödf.div.Kalke); V.1, VI.5; u-miBad; 23.
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9: BDA (CoA-K,Brekz,GrLum; IV.1; (m)oBd; 11.
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22: Weißes Kreuz; IV.1; oSarm; 3.
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16: Teufelsj., Zeilerbr.; I.1; (oBad-)uSarm; 23.
18: Breitenbr., Gruibert; I.4; uSarm; 28.
15: Atzgersdorfer Stein; V.4; oSarm; 12.
6: Mannersdorf-Baxa; II.1; u-miBad; 6.
8: Müllendorf; II.3; u-miBad; 6.
19: Au-Loretto-LorettoS; II.2; uSarm; 24.
7: Stotzing, SulzbgTeufelsloch; II.2; u-miBd;13.
20: Müllendorf Natdkm; II.3; u?Sarm; 4.
3: Oolithe Wolfsth, (Weinviert); IV.2; oSarm; 5.
25: divLith.Kleine Karpathen Slovakei; Bd; 6.
11: (Prinzendf.Weinviertel); miBd; 2.
2: Sdst. Heiligenst-Türkschpk,Schöbr; V.2, V.3; uSarm, Pannon; 24.
23: Winden, St.GeorgLgeb; I.4, II.3; Sarm?; 6.
21: St.Margarethen; III.1; obBd (uSarm?); 2.
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12: Ritzing-Fm.; oberst.miBaden; 2.
1: Flyschsdst. Sievg Greifst; obKr-Paläozän; 8.
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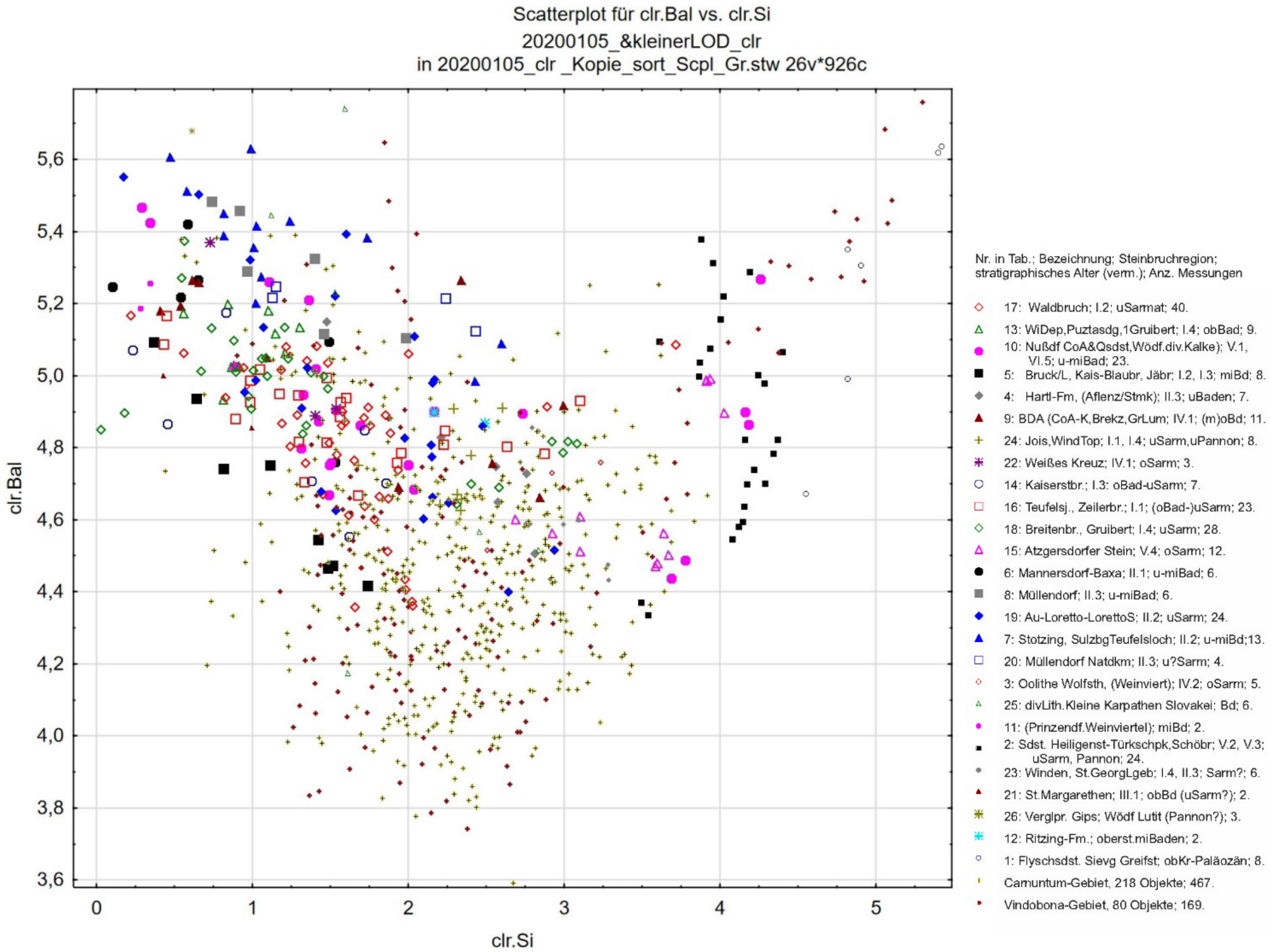
Vindobona-Gebiet, 80 Objekte; 169.


Scatterplot für clr.Bal vs. clr.Si
20200105_&kleinerLOD_clr
in 20200105_clr _Kopie_sort_Scpl_Gr.stw 26v*926c
clr.Bal
clr.Si
5,6
5,4
5,2
5,0
4,8
4,6
4,4
4,2
4,0
3,8
3,6
0
1
2
3
4
5
Nr. in Tab.; Bezeichnung; Steinbruchregion; stratigraphisches Alter (verm.); Anz. Messungen
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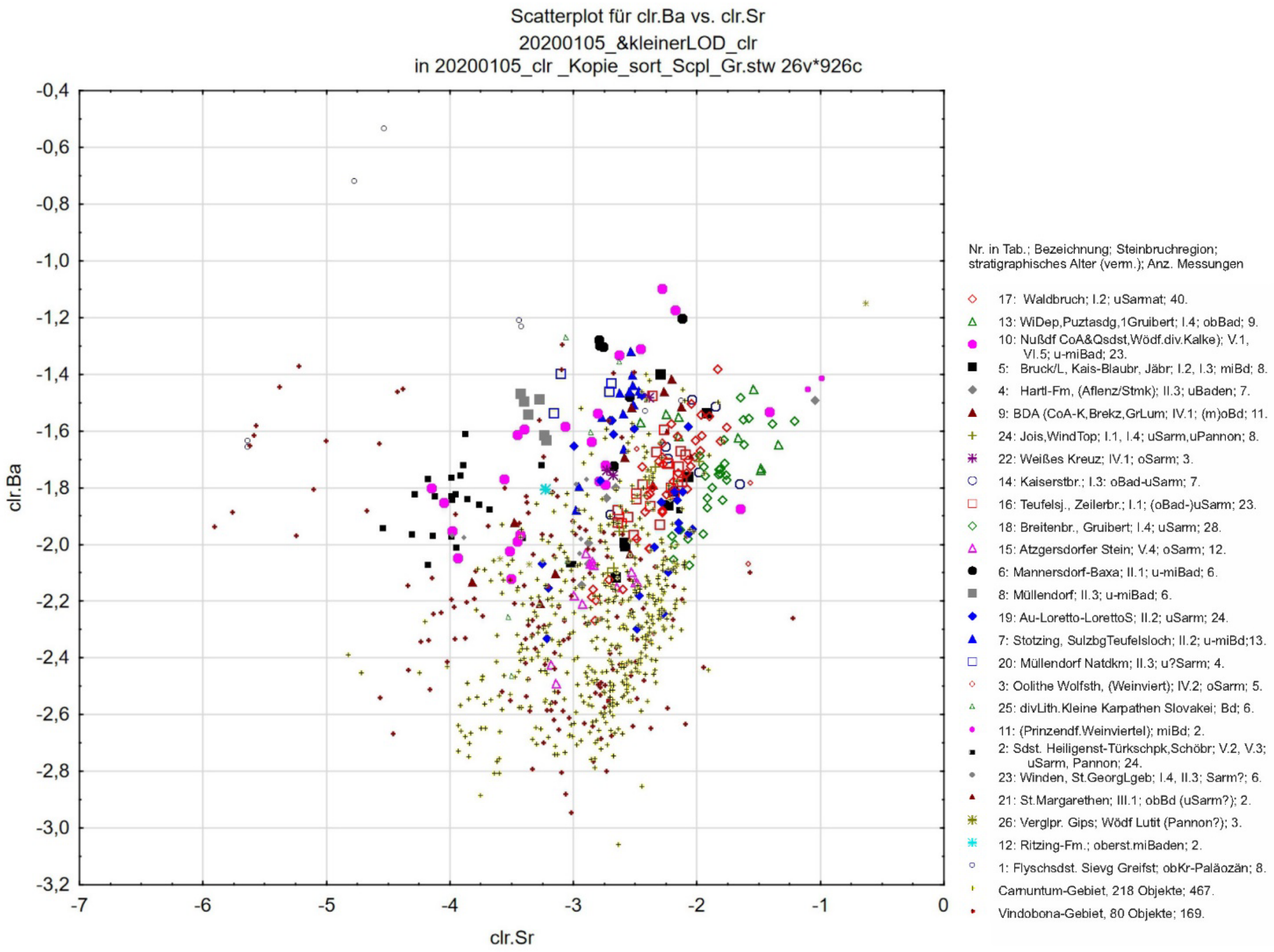
Scatterplot für clr.Ba vs. clr.Sr
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in 20200105_clr _Kopie_sort_Scpl_Gr.stw 26v*926c
clr.Ba
clr.Sr
Nr. in Tab.; Bezeichnung; Steinbruchregion; stratigraphisches Alter (verm.); Anz. Messungen
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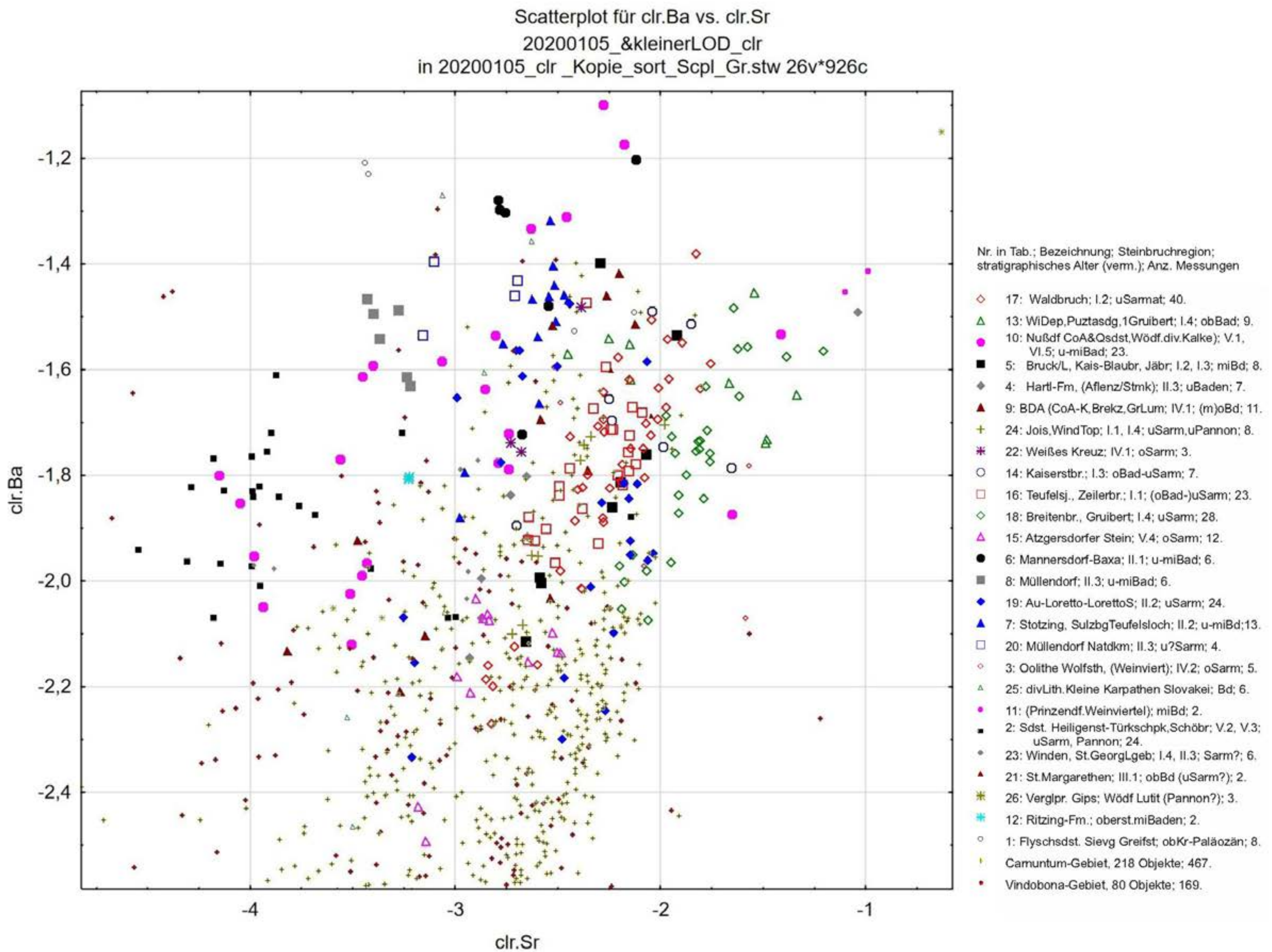
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in 20200105_clr _Kopie_sort_Scpl_Gr.stw 26v*926c
clr.Ba
-1,2
-1,4
-1,6
-1,8
-2,0
-2,2
-2,4
-4
-3
-2
-1
clr.Sr
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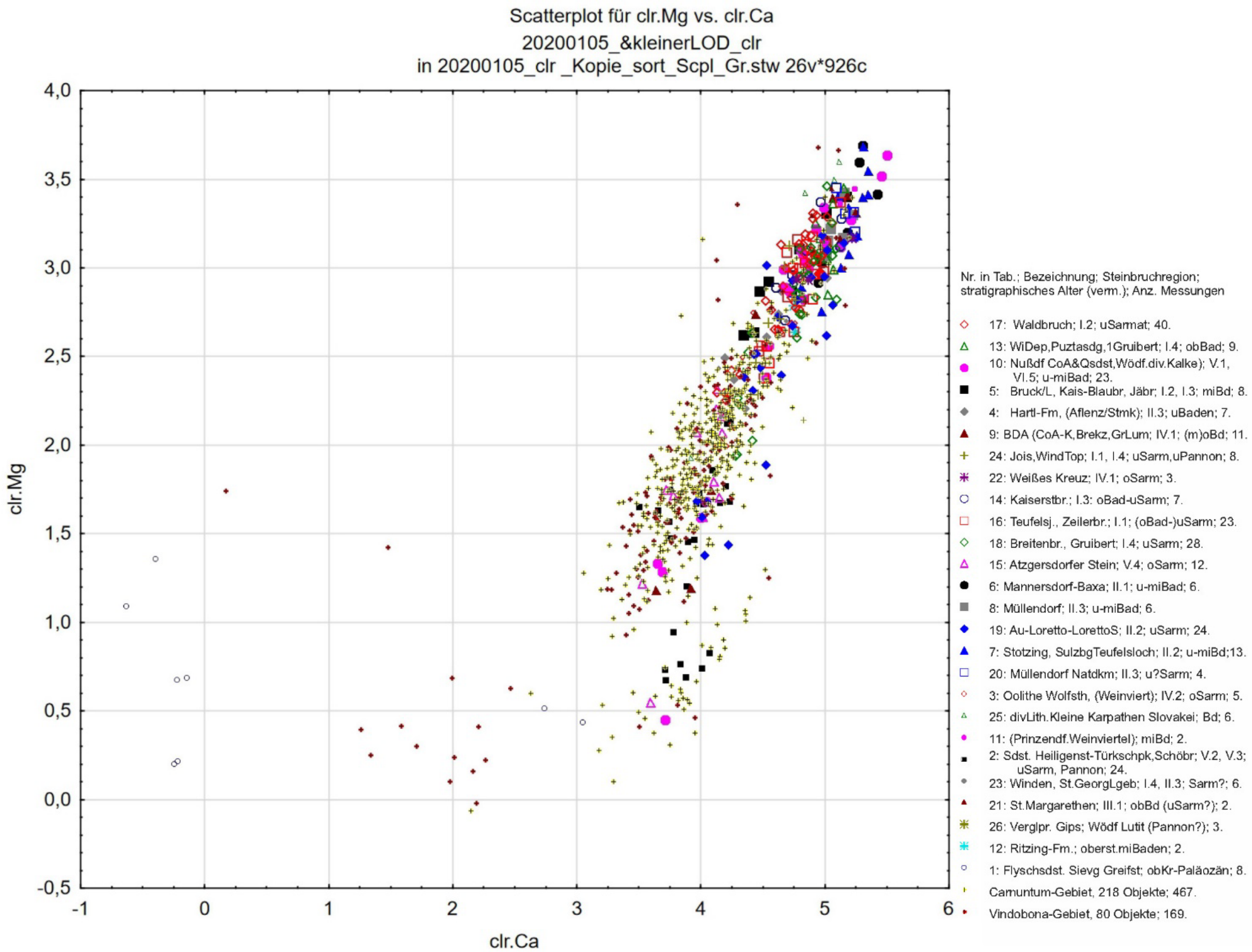
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clr.Mg
clr.Ca
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
-0,5
-1
0
1
2
3
4
5
6
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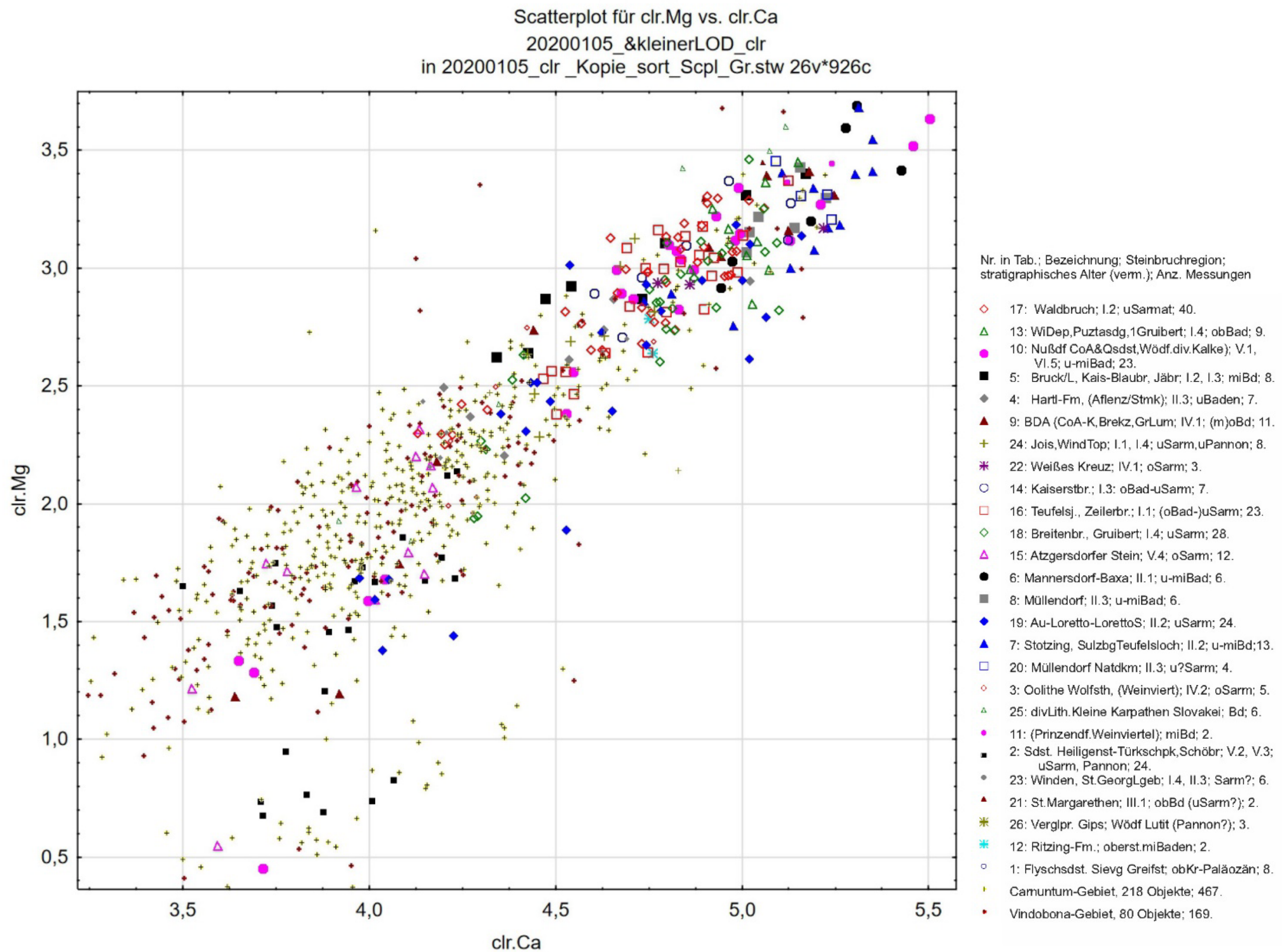
Scatterplot für clr.Mg vs. clr.Ca
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clr.Mg
3,5
3,0
2,5
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1,5
1,0
0,5
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3,5
4,0
4,5
5,0
5,5
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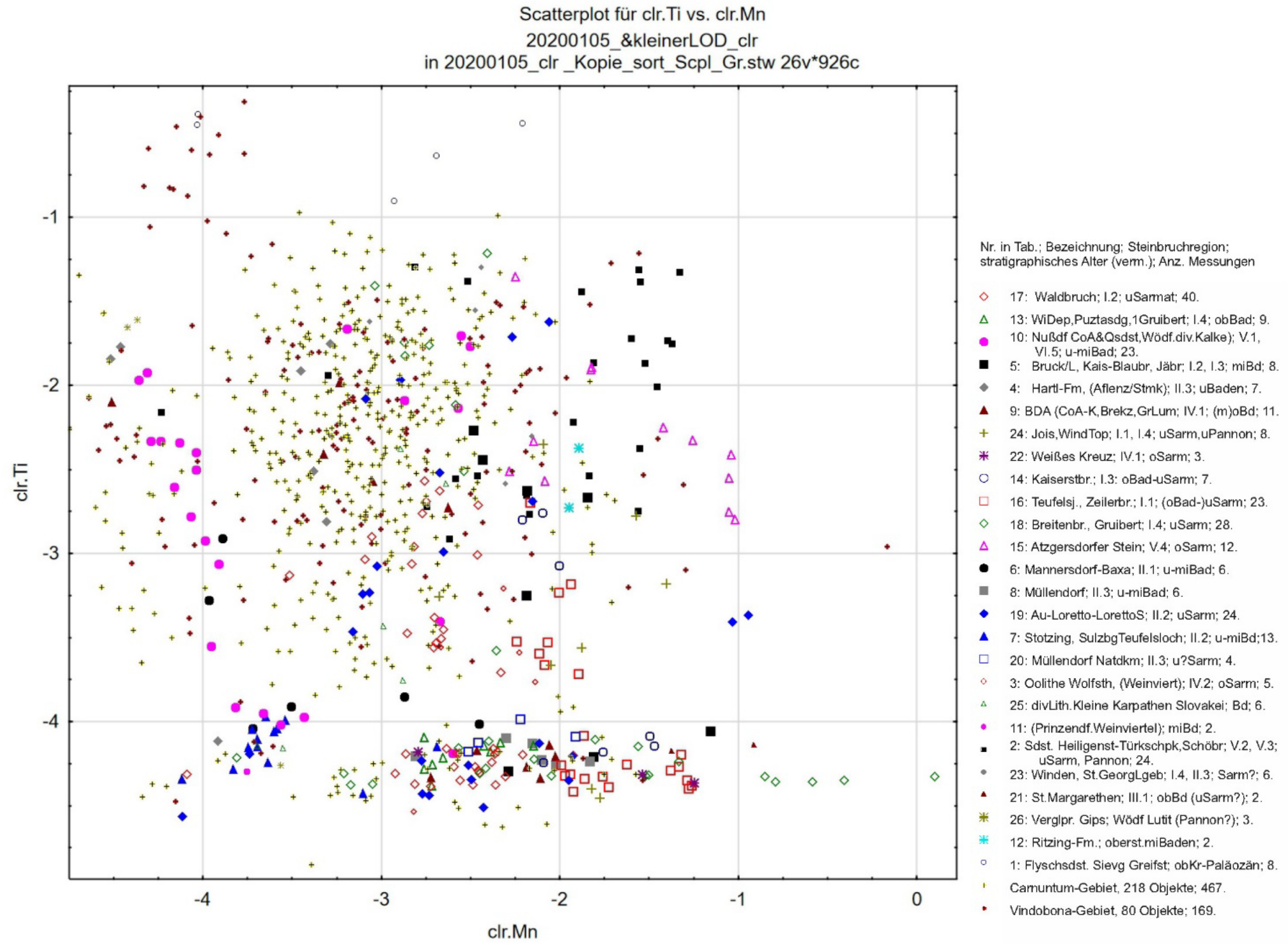
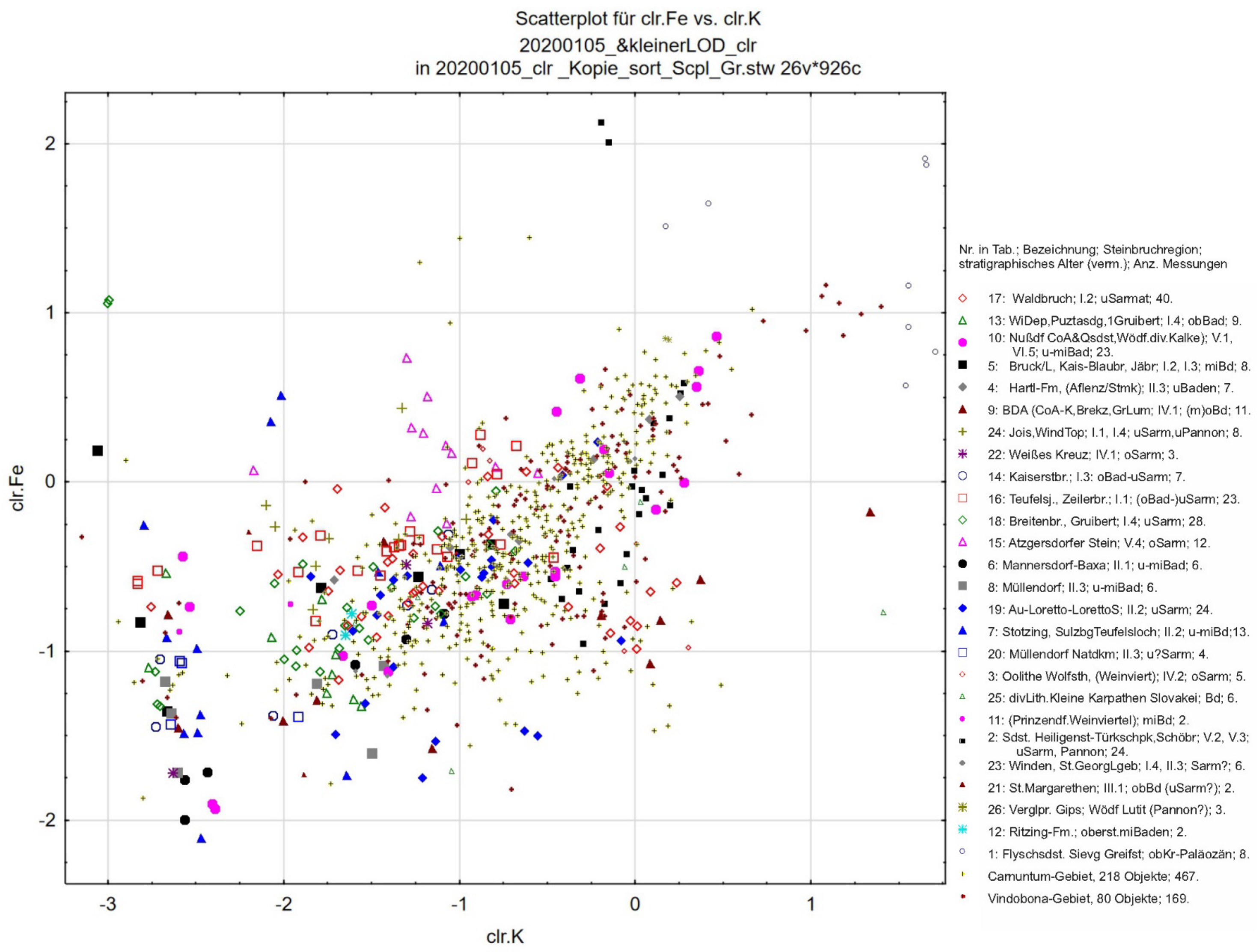
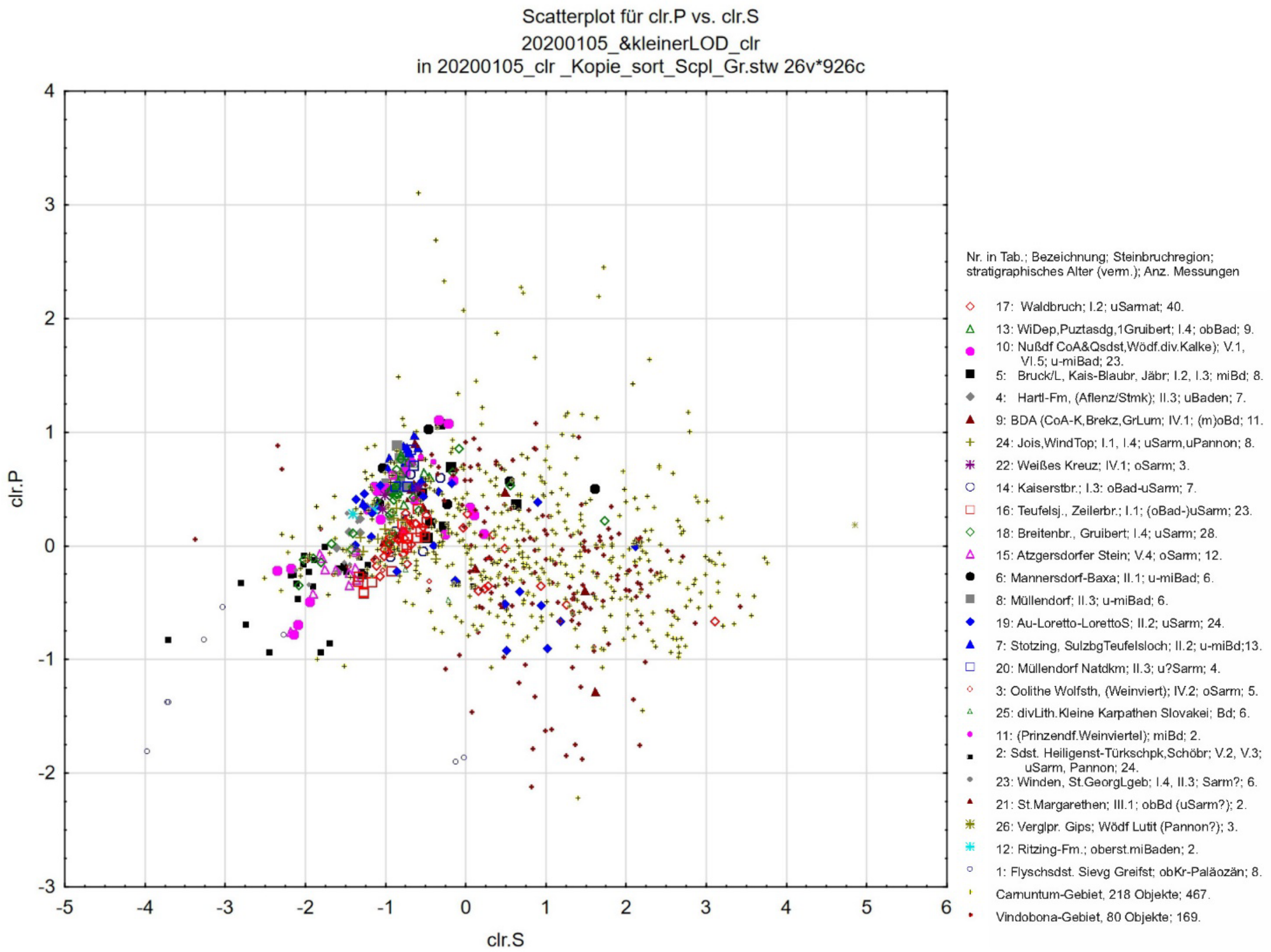
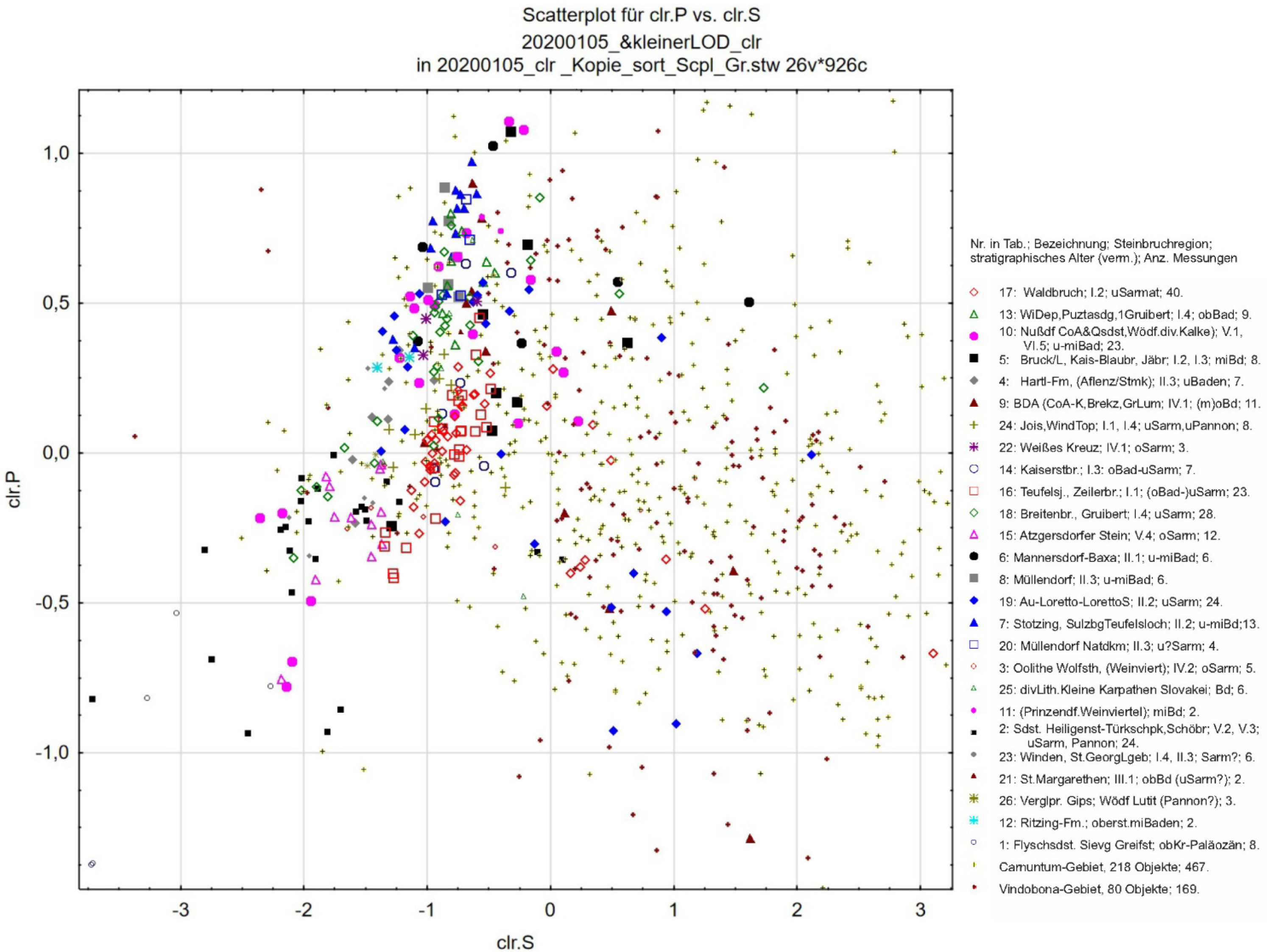

Scatterplot für clr.Ti vs. clr.Mn
20200105_&kleinerLOD_clr
in 20200105_clr _Kopie_sort_Scpl_Gr.stw 26v*926c
clr.Ti
clr.Mn
-1
-2
-3
-4
0
Nr. in Tab.; Bezeichnung; Steinbruchregion; stratigraphisches Alter (verm.); Anz. Messungen
17: Waldbruch; I.2; uSarmat; 40.
13: WiDep,Puztasdg,1Gruibert; I.4; obBad; 9.
10: Nußdf CoA&Qsdst,Wödf.div.Kalke); V.1, VI.5; u-miBad; 23.
5: Bruck/L, Kais-Blaubr, Jäbr; I.2, I.3; miBd; 8.
4: Hartl-Fm, (Aflenz/Stmk); II.3; uBaden; 7.
9: BDA (CoA-K,Brekz,GrLum; IV.1; (m)oBd; 11.
24: Jois,WindTop; I.1, I.4; uSarm,uPannon; 8.
22: Weißes Kreuz; IV.1; oSarm; 3.
14: Kaiserstbr.; I.3: oBad-uSarm; 7.
16: Teufelsj., Zeilerbr.; I.1; (oBad-)uSarm; 23.
18: Breitenbr., Gruibert; I.4; uSarm; 28.
15: Atzgersdorfer Stein; V.4; oSarm; 12.
6: Mannersdorf-Baxa; II.1; u-miBad; 6.
8: Müllendorf; II.3; u-miBad; 6.
19: Au-Loretto-LorettoS; II.2; uSarm; 24.
7: Stotzing, SulzbgTeufelsloch; II.2; u-miBd;13.
20: Müllendorf Natdkm; II.3; u?Sarm; 4.
3: Oolithe Wolfsth, (Weinviert); IV.2; oSarm; 5.
25: divLith.Kleine Karpathen Slovakei; Bd; 6.
11: (Prinzendf.Weinviertel); miBd; 2.
2: Sdst. Heiligenst-Türkschpk,Schöbr; V.2, V.3; uSarm, Pannon; 24.
23: Winden, St.GeorgLgeb; I.4, II.3; Sarm?; 6.
21: St.Margarethen; III.1; obBd (uSarm?); 2.
26: Verglpr. Gips; Wödf Lutit (Pannon?); 3.
12: Ritzing-Fm.; oberst.miBaden; 2.
1: Flyschsdst. Sievg Greifst; obKr-Paläozän; 8.
Carnuntum-Gebiet, 218 Objekte; 467.
Vindobona-Gebiet, 80 Objekte; 169.


Scatterplot für clr.Fe vs. clr.K
20200105_&kleinerLOD_clr
in 20200105_clr _Kopie_sort_Scpl_Gr.stw 26v*926c
clr.Fe
clr.K
2
1
0
-1
-2
-3
-2
-1
0
1
Nr. in Tab.; Bezeichnung; Steinbruchregion; stratigraphisches Alter (verm.); Anz. Messungen
17: Waldbruch; I.2; uSarmat; 40.
13: WiDep,Puztasdg,1Gruibert; I.4; obBad; 9.
10: Nußdf CoA&Qsdst,Wödf.div.Kalke); V.1, VI.5; u-miBad; 23.
5: Bruck/L, Kais-Blaubr, Jäbr; I.2, I.3; miBd; 8.
4: Hartl-Fm, (Aflenz/Stmk); II.3; uBaden; 7.
9: BDA (CoA-K,Brekz,GrLum; IV.1; (m)oBd; 11.
24: Jois,WindTop; I.1, I.4; uSarm,uPannon; 8.
22: Weißes Kreuz; IV.1; oSarm; 3.
14: Kaiserstbr.; I.3: oBad-uSarm; 7.
16: Teufelsj., Zeilerbr.; I.1; (oBad-)uSarm; 23.
18: Breitenbr., Gruibert; I.4; uSarm; 28.
15: Atzgersdorfer Stein; V.4; oSarm; 12.
6: Mannersdorf-Baxa; II.1; u-miBad; 6.
8: Müllendorf; II.3; u-miBad; 6.
19: Au-Loretto-LorettoS; II.2; uSarm; 24.
7: Stotzing, SulzbgTeufelsloch; II.2; u-miBd;13.
20: Müllendorf Natdkm; II.3; u?Sarm; 4.
3: Oolithe Wolfsth, (Weinviert); IV.2; oSarm; 5.
25: divLith.Kleine Karpathen Slovakei; Bd; 6.
11: (Prinzendf.Weinviertel); miBd; 2.
2: Sdst. Heiligenst-Türkschpk,Schöbr; V.2, V.3; uSarm, Pannon; 24.
23: Winden, St.GeorgLgeb; I.4, II.3; Sarm?; 6.
21: St.Margarethen; III.1; obBd (uSarm?); 2.
26: Verglpr. Gips; Wödf Lutit (Pannon?); 3.
12: Ritzing-Fm.; oberst.miBaden; 2.
1: Flyschsdst. Sievg Greifst; obKr-Paläozän; 8.
Carnuntum-Gebiet, 218 Objekte; 467.
Vindobona-Gebiet, 80 Objekte; 169.


Scatterplot für clr.P vs. clr.S
20200105_&kleinerLOD_clr
in 20200105_clr _Kopie_sort_Scpl_Gr.stw 26v*926c
clr.P
clr.S
4
3
2
1
0
-1
-2
-3
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
Nr. in Tab.; Bezeichnung; Steinbruchregion; stratigraphisches Alter (verm.); Anz. Messungen
17: Waldbruch; I.2; uSarmat; 40.
13: WiDep,Puztasdg,1Gruibert; I.4; obBad; 9.
10: Nußdf CoA&Qsdst,Wödf.div.Kalke); V.1, VI.5; u-miBad; 23.
5: Bruck/L, Kais-Blaubr, Jäbr; I.2, I.3; miBd; 8.
4: Hartl-Fm, (Aflenz/Stmk); II.3; uBaden; 7.
9: BDA (CoA-K,Brekz,GrLum; IV.1; (m)oBd; 11.
24: Jois,WindTop; I.1, I.4; uSarm,uPannon; 8.
22: Weißes Kreuz; IV.1; oSarm; 3.
14: Kaiserstbr.; I.3: oBad-uSarm; 7.
16: Teufelsj., Zeilerbr.; I.1; (oBad-)uSarm; 23.
18: Breitenbr., Gruibert; I.4; uSarm; 28.
15: Atzgersdorfer Stein; V.4; oSarm; 12.
6: Mannersdorf-Baxa; II.1; u-miBad; 6.
8: Müllendorf; II.3; u-miBad; 6.
19: Au-Loretto-LorettoS; II.2; uSarm; 24.
7: Stotzing, SulzbgTeufelsloch; II.2; u-miBd;13.
20: Müllendorf Natdkm; II.3; u?Sarm; 4.
3: Oolithe Wolfsth, (Weinviert); IV.2; oSarm; 5.
25: divLith.Kleine Karpathen Slovakei; Bd; 6.
11: (Prinzendf.Weinviertel); miBd; 2.
2: Sdst. Heiligenst-Türkschpk,Schöbr; V.2, V.3; uSarm, Pannon; 24.
23: Winden, St.GeorgLgeb; I.4, II.3; Sarm?; 6.
21: St.Margarethen; III.1; obBd (uSarm?); 2.
26: Verglpr. Gips; Wödf Lutit (Pannon?); 3.
12: Ritzing-Fm.; oberst.miBaden; 2.
1: Flyschsdst. Sievg Greifst; obKr-Paläozän; 8.
Carnuntum-Gebiet, 218 Objekte; 467.
Vindobona-Gebiet, 80 Objekte; 169.


Scatterplot für clr.P vs. clr.S
20200105_&kleinerLOD_clr
in 20200105_clr _Kopie_sort_Scpl_Gr.stw 26v*926c
clr.P
1,0
0,5
0,0
-0,5
-1,0
clr.S
-3
-2
-1
0
1
2
3
Nr. in Tab.; Bezeichnung; Steinbruchregion; stratigraphisches Alter (verm.); Anz. Messungen
17: Waldbruch; I.2; uSarmat; 40.
13: WiDep,Puztasdg,1Gruibert; I.4; obBad; 9.
10: Nußdf CoA&Qsdst,Wödf.div.Kalke); V.1, VI.5; u-miBad; 23.
5: Bruck/L, Kais-Blaubr, Jäbr; I.2, I.3; miBd; 8.
4: Hartl-Fm, (Aflenz/Stmk); II.3; uBaden; 7.
9: BDA (CoA-K,Brekz,GrLum; IV.1; (m)oBd; 11.
24: Jois,WindTop; I.1, I.4; uSarm,uPannon; 8.
22: Weißes Kreuz; IV.1; oSarm; 3.
14: Kaiserstbr.; I.3: oBad-uSarm; 7.
16: Teufelsj., Zeilerbr.; I.1; (oBad-)uSarm; 23.
18: Breitenbr., Gruibert; I.4; uSarm; 28.
15: Atzgersdorfer Stein; V.4; oSarm; 12.
6: Mannersdorf-Baxa; II.1; u-miBad; 6.
8: Müllendorf; II.3; u-miBad; 6.
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7: Stotzing, SulzbgTeufelsloch; II.2; u-miBd;13.
20: Müllendorf Natdkm; II.3; u?Sarm; 4.
3: Oolithe Wolfsth, (Weinviert); IV.2; oSarm; 5.
25: divLith.Kleine Karpathen Slovakei; Bd; 6.
11: (Prinzendf.Weinviertel); miBd; 2.
2: Sdst. Heiligenst-Türkschpk,Schöbr; V.2, V.3; uSarm, Pannon; 24.
23: Winden, St.GeorgLgeb; I.4, II.3; Sarm?; 6.
21: St.Margarethen; III.1; obBd (uSarm?); 2.
26: Verglpr. Gips; Wödf Lutit (Pannon?); 3.
12: Ritzing-Fm.; oberst.miBaden; 2.
1: Flyschsdst. Sievg Greifst; obKr-Paläozän; 8.
Carnuntum-Gebiet, 218 Objekte; 467.
Vindobona-Gebiet, 80 Objekte; 169.

The publication of these results takes place within

the final report of the project

Stone Monuments and Stone Quarrying in the

Carnuntum - Vindobona Area

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and Erich Draganits, Department of Geodynamics and Sedimentology, Universität Wien