NMFk analysis: Geothermal data of Brady site, NV

This analysis demonstrates how **NMFk** can be applied to perform unsupervised machine-learning analysis.

The code below demonstrates the ML work for a submitted reseasrch paper analyzing geothermal data of Brady site, NV

Import required Julia modules

If **NMFk** is not installed, first execute `import Pkg; Pkg.add("NMFk"); Pkg.add("DelimitedFiles"); Pkg.add("Gadfly"); Pkg.add("Mads")` .

In [7]:
```
import NMFk
import DelimitedFiles
import Gadfly
import Cairo
import Fontconfig
import Mads
```

Unable to load WebIO. Please make sure WebIO works for your Jupyter client. For troubleshooting, please see [the WebIO/IJulia documentation (https://juliagizmos.github.io/WebIO.jl/latest/providers/ijulia/)](https://juliagizmos.github.io/WebIO.jl/latest/providers/ijulia/).

```
[ Info: Installing pyqt package to avoid buggy tkagg backend.
@ PyPlot /Users/vvv/.julia/packages/PyPlot/XHEG0/src/init.jl:118
```

Read Brady dataset

Setup the working directory containing Brady date

In [8]:
```
cd("/Users/vvv/Julia/GTcloud-SmartTensors.jl/Brady")
```

Load the datafile

In [10]:
```
d, h = DelimitedFiles.readdlm("data/AllBradyWells_LANL_ML_9.txt", ','; head
```

Populate the missing wellnames

In [11]:
```
global wellname = ""
for i = 1:size(d, 1)
    if d[i, 1] != ""
        global wellname = d[i, 1]
    else
        d[i, 1] = wellname
    end
end
```

Set missing entries to be equal to zero

In [14]:
```
d[d[:, 24] .== "", 24] .= 0;
```

In [ ]:
```
## Set up depth, casename, # of NMFk runs, and attributes
```

Define names of the data attributes (matrix columns; short names used for coding; long names used for plotting and visualization)

In [15]:
```
attributes_short = ["ID", "D", "azimuth", "incline", "x", "y", "z", "casing
attributes_long = ["ID", "Depth", "Azimuth", "Inclination", "X", "Y", "Z",
```

Define the attributes that will be processed

In [17]:
```
attributes_process = ["normal", "coulomb", "dilation", "faults", "td", "ts"
```

Index the attributes that will be processed

In [19]:
```
ai = indexin(attributes_process, attributes_short)
pr = indexin(["production"], attributes_short)
attributes_process_long = attributes_long[ai]

attributes_col = vec(permutedims(h))
attributes = attributes_col[ai];
```

Output information about the processed data (min, max, count):

In [20]:
```
for i=1:length(attributes_col); @info attributes_col[i], i; display([minimu
for i=1:length(attributes_col); @info attributes_col[i], i; display(unique(
```

```
2-element Array{SubString{String},1}:
 "15-12"
 "MGI-2"

┌ Info: ("wellid", 1)
└ @ Main In[20]:1
┌ Info: ("md", 2)
└ @ Main In[20]:1

2-element Array{Float64,1}:
    0.0
 2213.723

2-element Array{Float64,1}:
   0.0
 359.991

2-element Array{Float64,1}:
   0.0
 359.963
```

Get well locations and production

In [22]:
```
locations = unique(sort(d[:,1]))
ii = convert.(Int64, round.(d[:,2]))
zi = unique(sort(ii))

xcoord = Vector{Float64}(undef, length(locations))
ycoord = Vector{Float64}(undef, length(locations))
production = Vector{String}(undef, length(locations))
for (j, w) in enumerate(locations)
    iw = d[:, 1] .== w
    i = findmin(d[iw, 2])[2]
    xcoord[j] = d[iw, 5][i]
    ycoord[j] = d[iw, 6][i]
    production[j] = unique(d[iw, pr])[end]
end
```

Define well types

In [23]:
```
welltype = Vector{Symbol}(undef, length(locations))
for (j, w) in enumerate(locations)
    iw = d[:, 1] .== w
    welltype[j] = Symbol(unique(d[iw, indexin(["lt750mstatus"], attributes_
end
```

Show information for different attributes

In [24]:
```
for i = ai
    @info attributes_col[i], i
    display(unique(sort(convert.(Float64, d[:,i]))))
end
```

```
34981-element Array{Float64,1}:
 -100.6743850708
 -100.673828125
 -100.67253875732
 -100.67088317871
 -100.66828155518
 -100.66556549072
 -100.66159057617
 -100.65789031982
 -100.65245819092
 -100.6478729248
 -100.64087677002
 -100.63552856445
 -100.62683105469
    ⋮
  153.09405517578
  153.41345214844
  153.7287902832
  154.04025268555
```

Colect the well data into 3D tensor with indices defining depths, attributes, and wells

In [25]:
```
T = Array{Float64}(undef, length(zi), length(ai), length(locations))
T .= NaN

for w = 1:length(locations)
    iw = d[:, 1] .== locations[w]
    m = d[iw, ai]
    zw = ii[iw]
    for z = 1:length(zw)
        a = vec(m[z, :])
        s = length(a)
        if s == 0
            continue
        end
        T[zw[z] + 1, 1:s, w] .= a
    end
end
```

Define the max depth of the data included in the analyses (750 m was selected)

In [27]:
```
depth = 750;
```

Normalize the tensor slices assoicated with each attribute

In [28]:
```
Tn = deepcopy(T[1:depth,:,:])
for a = 1:length(ai)
    Tn[:,a,:], _, _ = NMFk.normalize!(Tn[:,a,:])
end
```

Define problem setup variables

In [31]:
```
nruns = 1000 # Number of random NMF runs
nkrange = 2:8 # range of k values

casename = "set00-v9-inv"
figuredir = "figures-$(casename)-$(depth)"
resultdir = "results-$(casename)-$(depth)";
```

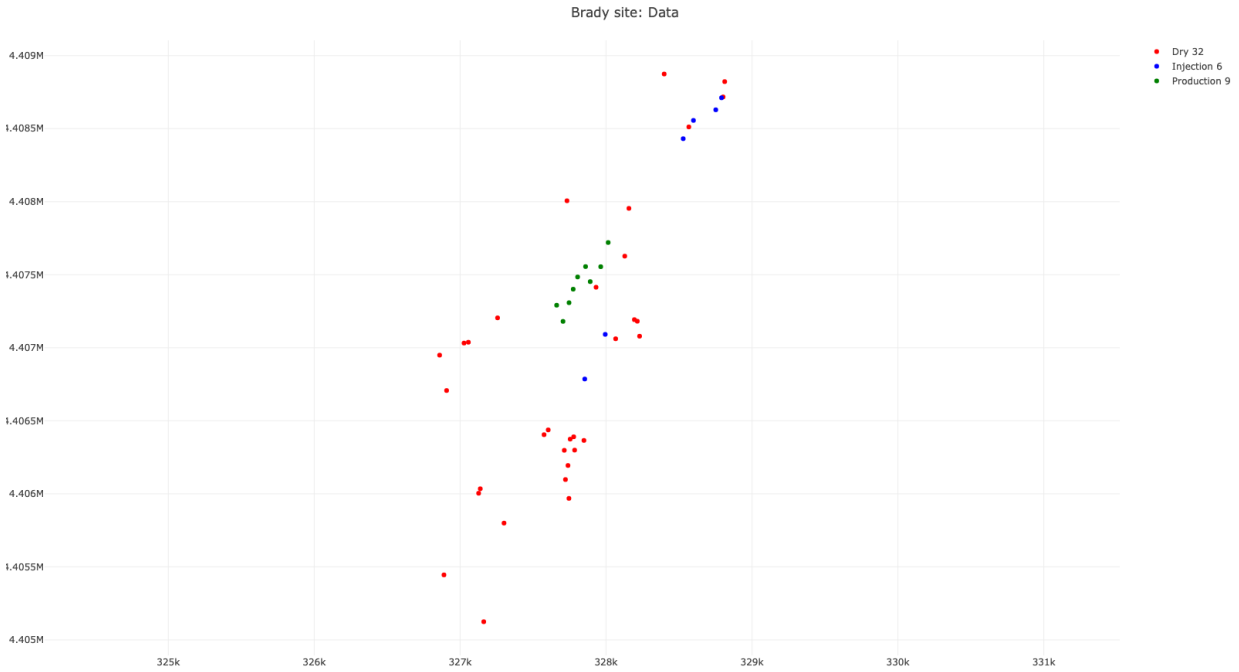
Plot well data

In [32]:
```
nlocations = length(locations)
hovertext = Vector{String}(undef, nlocations)
for i = 1:nlocations
    hovertext[i] = join(map(j->("$(attributes_process_long[j]): $(round(flo
end

NMFk.plot_wells("map/dataset-$(casename).html", xcoord, ycoord, String.(wel
```

HTML file named "map/dataset-set00-v9-inv.html" is generated; it provides interacive visualization of the data.

PNG version of the map looks like this:

In [46]:
```
display("image/png", read("./map/dataset-set01-v9-inv.png"))
```



ML analysis

For the ML analyses, the data tensor will be flatten two differnt ways.

Flatten the tensor into a matrix (type 1)

Matrix rows merge the depth and attribute dimensions.

Matrix cols represent the well locations.

In [51]:
```
Xdaln = reshape(Tn, ((depth * length(attributes_process))), length(location
```

Perform NMFk analyses

Here the **NMFk** results are loaded from a prior ML runs.

In [55]:
```
W, H, fitquality, robustness, aic = NMFk.execute(Xdaln, nkrange, nruns; res
W, H, fitquality, robustness, aic = NMFk.load(nkrange, nruns; resultdir=res
```

```
Signals:  2 Fit:     17906.11 Silhouette:    0.6571116 AIC:    -944054.7
Signals:  3 Fit:     15067.48 Silhouette:    0.2121185 AIC:    -981003.7
Signals:  4 Fit:     12811.86 Silhouette:  -0.03854946 AIC:     -1014443
Signals:  5 Fit:     10966.81 Silhouette:    0.4108927 AIC:     -1045640
Signals:  6 Fit:     9570.522 Silhouette:    0.4704617 AIC:     -1070343
Signals:  7 Fit:     8398.009 Silhouette:   -0.2070509 AIC:     -1093198
Signals:  8 Fit:     7428.398 Silhouette:   -0.2601539 AIC:     -1113361
Signals:  2 Fit:     17906.11 Silhouette:    0.6571116 AIC:    -944054.7
Signals:  3 Fit:     15067.48 Silhouette:    0.2121185 AIC:    -981003.7
Signals:  4 Fit:     12811.86 Silhouette:  -0.03854946 AIC:     -1014443
Signals:  5 Fit:     10966.81 Silhouette:    0.4108927 AIC:     -1045640
Signals:  6 Fit:     9570.522 Silhouette:    0.4704617 AIC:     -1070343
Signals:  7 Fit:     8398.009 Silhouette:   -0.2070509 AIC:     -1093198
Signals:  8 Fit:     7428.398 Silhouette:   -0.2601539 AIC:     -1113361
Signals:  2 Fit:     17906.11 Silhouette:    0.6571116 AIC:    -944054.7
Signals:  3 Fit:     15067.48 Silhouette:    0.2121185 AIC:    -981003.7
Signals:  4 Fit:     12811.86 Silhouette:  -0.03854946 AIC:     -1014443
┌ Info: Results
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkExecute.jl:15
┌ Info: Optimal solution: 6 signals
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkExecute.jl:20
Signals:  5 Fit:     10966.81 Silhouette:    0.4108927 AIC:     -1045640
Signals:  6 Fit:     9570.522 Silhouette:    0.4704617 AIC:     -1070343
Signals:  7 Fit:     8398.009 Silhouette:   -0.2070509 AIC:     -1093198
Signals:  8 Fit:     7428.398 Silhouette:   -0.2601539 AIC:     -1113361
┌ Info: Optimal solution: 6 signals
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkIO.jl:30
```

As seen from the output the ML analyses identified that the optimal number of geothermal signatures in the dataset **6**.

Solutions with a number of signatures less than **6** are underfitting.

Solutions with a number of signatures greater than **6** are overfitting and unacceptable.

The set of accetable solutions are defined as follows:

In [58]:
```
NMFk.getks(nkrange, robustness[nkrange])
```

Out[58]:
```
3-element Array{Int64,1}:
 2
 5
 6
```

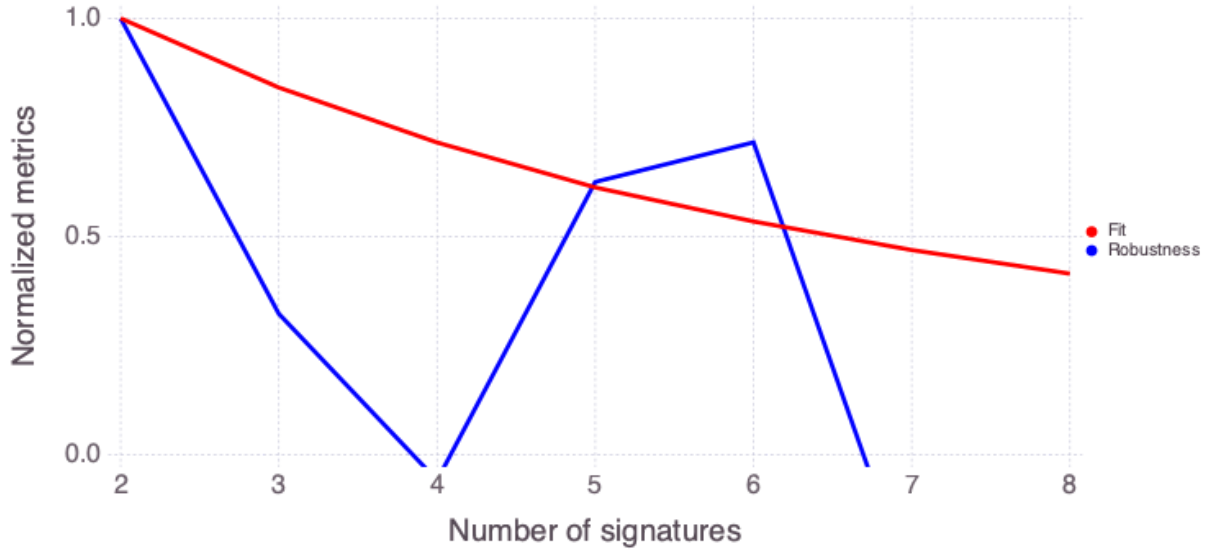
The accceptable solutions contain 2, 5 and 6 signatures.

Plot results

Plot representing solution quality (fit) and silhouette width (robistness) for different number of sigantures `k` :

In [ ]:

In [60]:
```
NMFk.plot_signal_selecton(nkrange, fitquality, robustness; figuredir="$figu
```

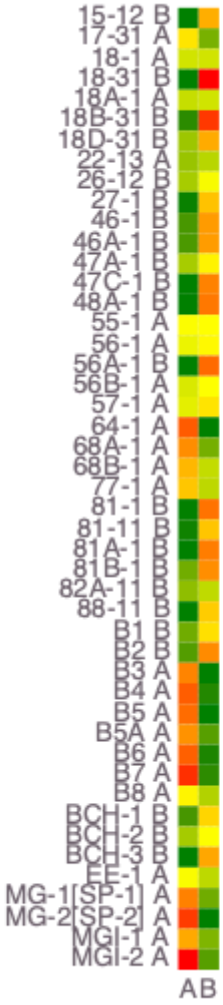


The ML solutions containing 2, 5 and 6 signatures are further analyzed as follows:

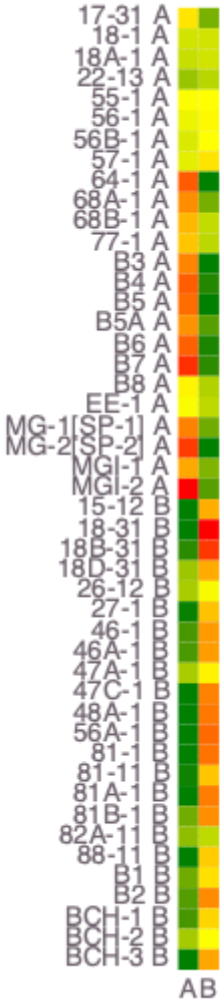
In [62]:
```
NMFk.clusterresults(NMFk.getks(nkrange, robustness[nkrange]), W, H, attribu
```

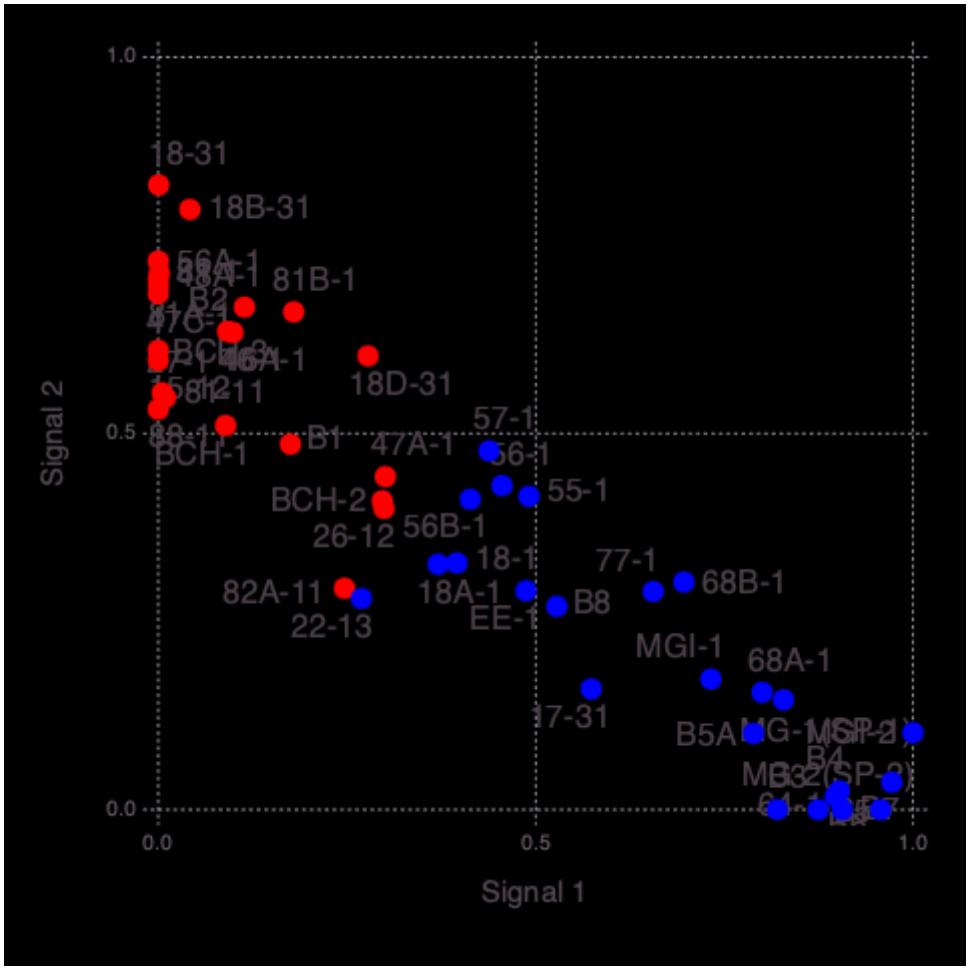
```
┌ Info: Number of signals: 2
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:144
Signal importance (high->low): [2, 1]
┌ Info: Locations (signals=2)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:148
┌ Warning: type Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.F
loat64,Core.Int64} not present in workspace; reconstructing
└ @ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
┌ Info: Robust k-means analysis results are loaded from file results-set0
0-v9-inv-750-1000-daln/Hmatrix-2-2_47-1000.jld!
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: type Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.F
loat64,Core.Int64} not present in workspace; reconstructing
└ @ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
┌ Info: Robust k-means analysis results are loaded from file results-set0
0-v9-inv-750-1000-daln/Wmatrix-2-2_14-1000.jld!
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Info: Signal A -> A Count: 24
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255

24×2 Array{Any,2}:
 "MGI-2"       1.0
 "B7"          0.971874
 "MG-2(SP-2)"  0.957147
 "64-1"        0.906381
 "B4"          0.902571
 "B6"          0.897107
 "B5"          0.874384
 "MG-1(SP-1)"  0.828417
 "B3"          0.82034
 "68A-1"       0.80013
 "B5A"         0.78864
 "MGI-1"       0.732217
 "68B-1"       0.696522
 "77-1"        0.655878
 "17-31"       0.57376
 "B8"          0.528089
 "55-1"        0.491206
 "EE-1"        0.487324
 "56-1"        0.455524
 "57-1"        0.43842
 "56B-1"       0.413443
 "18-1"        0.395716
```

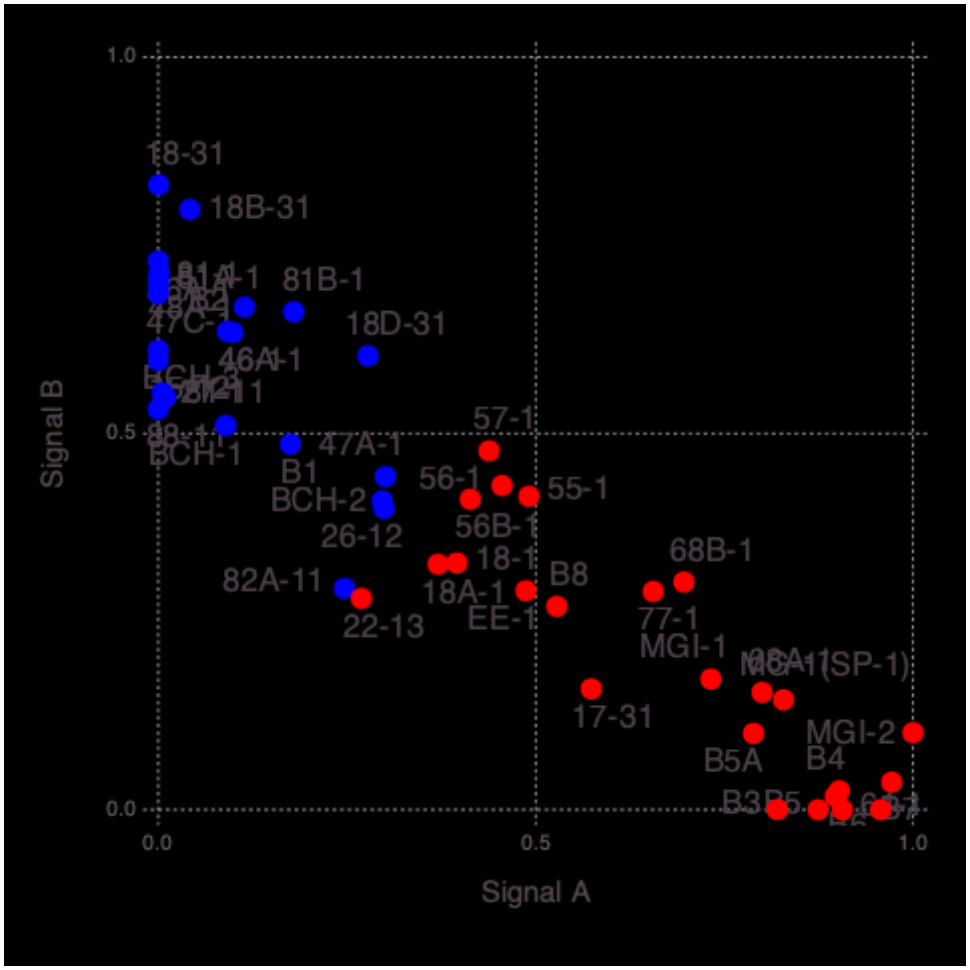
```
 "18A-1"       0.370733
 "22-13"       0.269227

┌ Info: Signal B -> B Count: 23
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal A (S1) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272

23×2 Array{Any,2}:
 "18-31"   1.0
 "18B-31"  0.960836
 "56A-1"   0.878124
 "81-1"    0.859001
 "48A-1"   0.849051
 "81A-1"   0.838298
 "47C-1"   0.826181
 "B2"      0.804453
 "81B-1"   0.796872
 "46-1"    0.765556
 "46A-1"   0.763833
 "BCH-3"   0.735382
 "18D-31"  0.726398
 "15-12"   0.719203
 "27-1"    0.66714
 "81-11"   0.659873
 "88-11"   0.641011
 "BCH-1"   0.61491
 "B1"      0.58518
 "47A-1"   0.533141
 "BCH-2"   0.494268
 "26-12"   0.482354
 "82A-11"  0.354477
```



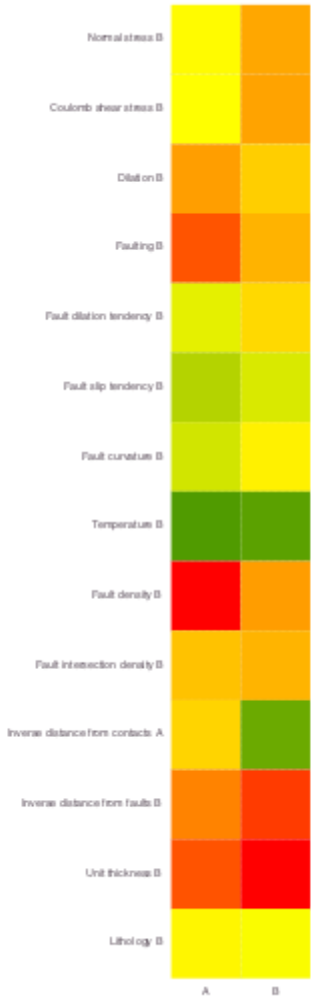

```
┌ Info: Signal B (S2) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
```


17-31 A
18-1 A
18A-1 A
22-13 A
55-1 A
56-1 A
56B-1 A
57-1 A
64-1 A
68A-1 A
68B-1 A
77-1 A
B3 A
B4 A
B5 A
B5A A
B6 A
B7 A
B8 A
EE-1 A
MG-1[SP-1] A
MG-2[SP-2] A
MGI-1 A
MGI-2 A
15-12 B
18-31 B
18B-31 B
18D-31 B
26-12 B
27-1 B
46-1 B
46A-1 B
47A-1 B
47C-1 B
48A-1 B
56A-1 B
81-1 B
81-11 B
81A-1 B
81B-1 B
82A-11 B
88-11 B
B1 B
B2 B
BCH-1 B
BCH-2 B
BCH-3 B
A B

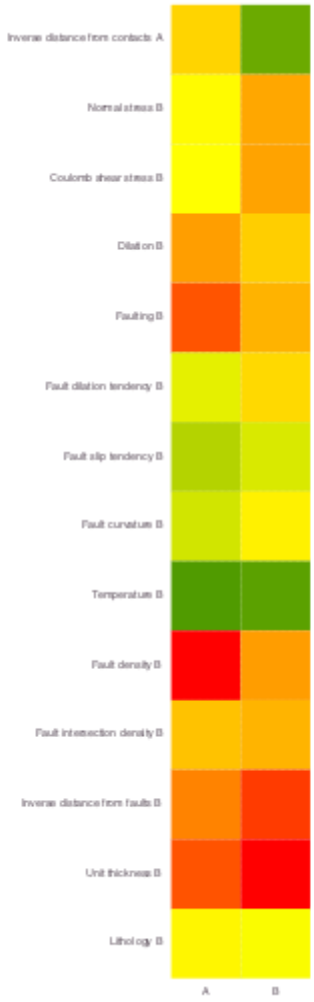

1.0
0.5
0.0
0.0
0.5
1.0
Signal 2
Signal 1
18-31
18B-31
81B-1
B2
18D-31
BCH-1
B1
47A-1
57-1
56-1
55-1
BCH-2
26-12
56B-1
18-1
77-1
68B-1
82A-11
18A-1
B8
22-13
MGI-1
68A-1
17-31
B5A
B4

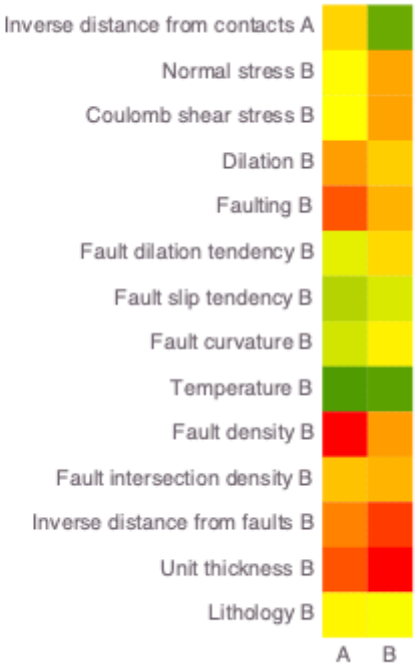

1.0
0.5
0.0
0.0
0.5
1.0
Signal B
Signal A
18-31
18B-31
81B-1
18D-31
47A-1
BCH-1
B1
BCH-2
26-12
57-1
56-1
55-1
56B-1
18-1
18A-1
B8
EE-1
82A-11
22-13
68B-1
77-1
MGI-1
17-31
MGI-2
B5A
B4

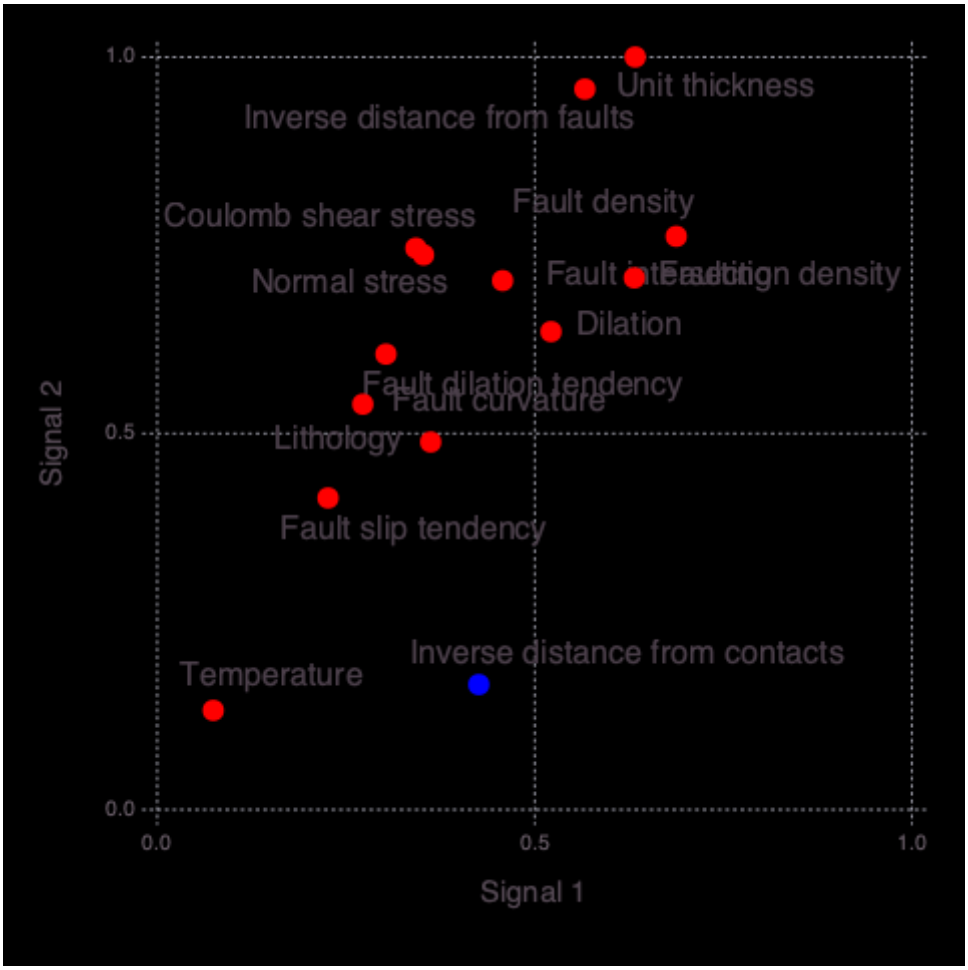
```
1×2 Array{Any,2}:
 "Inverse distance from contacts"  0.619519

13×2 Array{Any,2}:
 "Unit thickness"                 1.0
 "Inverse distance from faults"   0.957468
 "Fault density"                  0.761708
 "Coulomb shear stress"           0.74607
 "Normal stress"                  0.737061
 "Faulting"                       0.706576
 "Fault intersection density"     0.702918
 "Dilation"                       0.635119
 "Fault dilation tendency"        0.605243
 "Fault curvature"                0.538705
 "Lithology"                      0.488473
 "Fault slip tendency"            0.41415
 "Temperature"                    0.131901
```

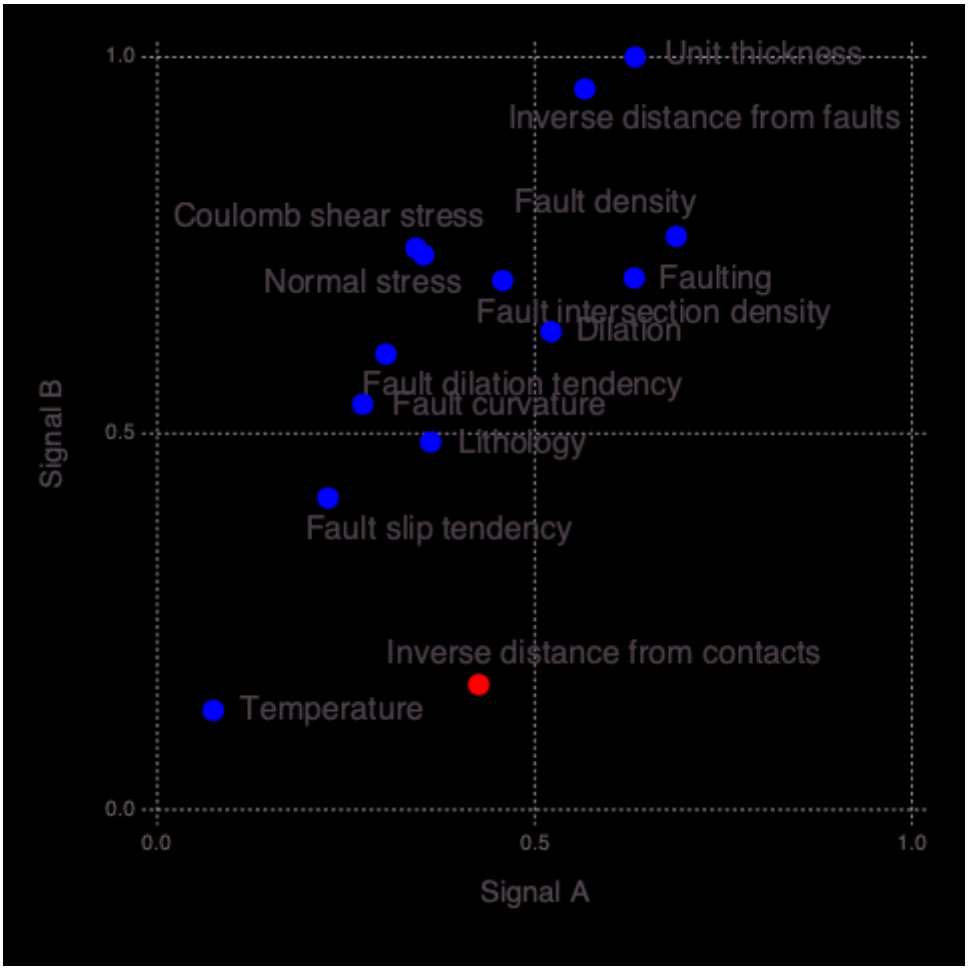


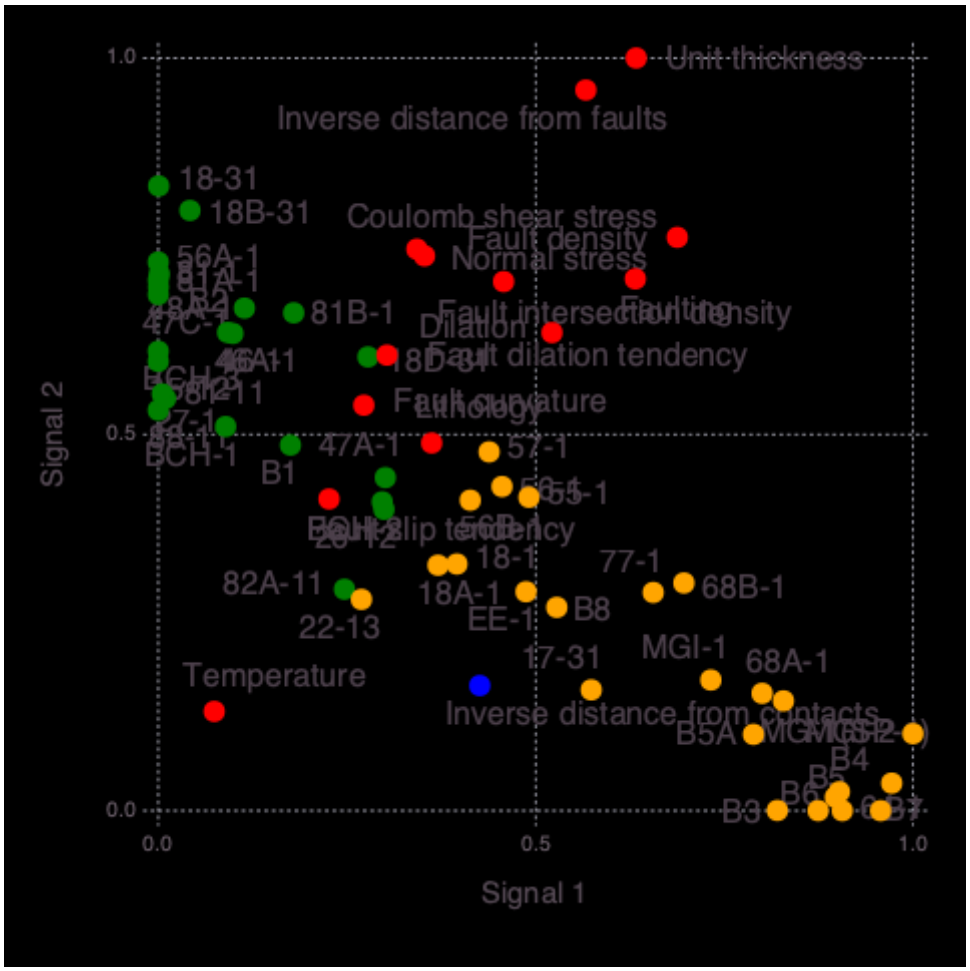

```
[ Info: Attributes (signals=2)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:322
[ Info: Signal A (S2) Count: 13
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal B (S1) Count: 1
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal B -> A Count: 1
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal A -> B Count: 13
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal A (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
[ Info: Signal B (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
```

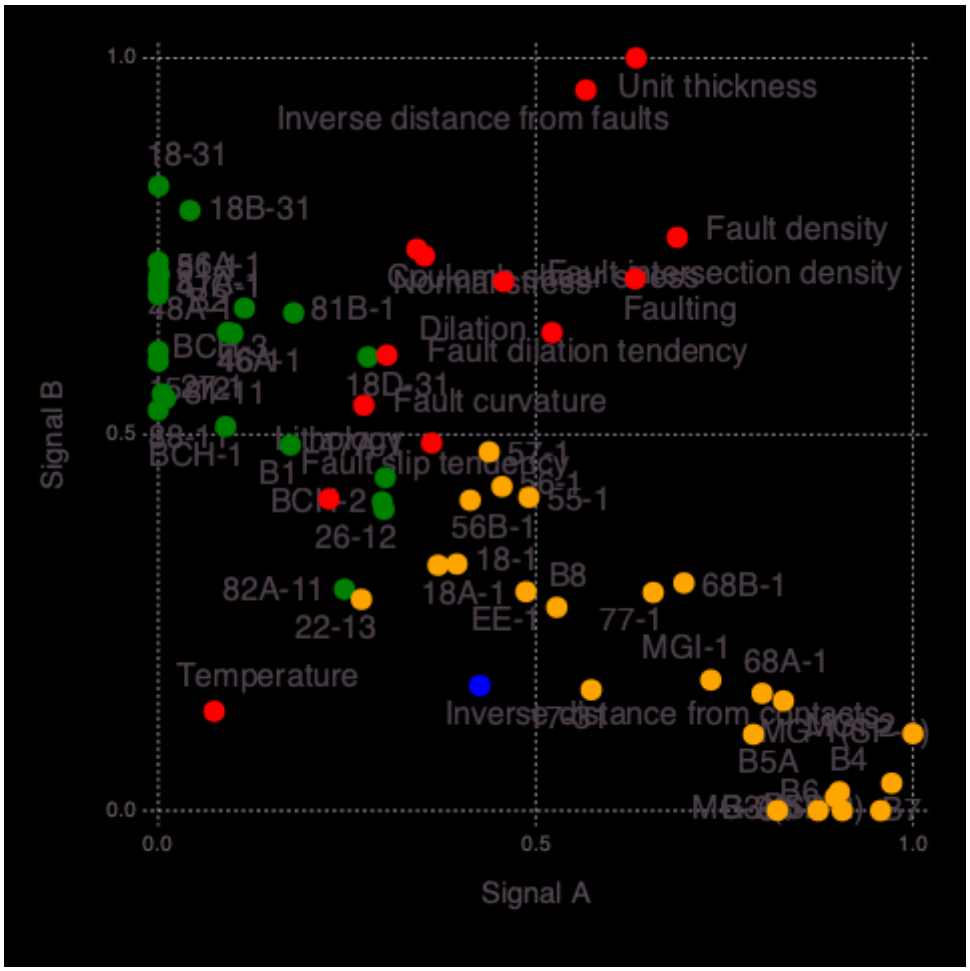

Inverse distance from contacts A
Normal stress B
Coulomb shear stress B
Dilation B
Faulting B
Fault dilation tendency B
Fault slip tendency B
Fault curvature B
Temperature B
Fault density B
Fault intersection density B
Inverse distance from faults B
Unit thickness B
Lithology B
A
B


Inverse distance from contacts A
Normal stress B
Coulomb shear stress B
Dilation B
Faulting B
Fault dilation tendency B
Fault slip tendency B
Fault curvature B
Temperature B
Fault density B
Fault intersection density B
Inverse distance from faults B
Unit thickness B
Lithology B
A
B


Unit thickness
Inverse distance from faults
Fault density
Coulomb shear stress
Normal stress
Dilation
Fault curvature
Lithology
Fault slip tendency
Inverse distance from contacts
Temperature
1.0
0.5
0.0
0.0
0.5
1.0
Signal 2
Signal 1


Unit thickness
Inverse distance from faults
Fault density
Coulomb shear stress
Faulting
Normal stress
Fault intersection density
Dilation
Fault dilation tendency
Fault curvature
Lithology
Fault slip tendency
Inverse distance from contacts
Temperature
1.0
0.5
0.0
Signal B
0.0
0.5
1.0
Signal A


Unit thickness
Inverse distance from faults
18-31
18B-31
Coulomb shear stress
Fault density
Normal stress
56A-1
81B-1
Fault intersection density
Dilation
Faulting
Fault dilation tendency
Fault curvature
Lithology
47A-1
57-1
B1
Slip tendency
18-1
77-1
82A-11
18A-1
68B-1
EE-1
B8
22-13
17-31
MGI-1
68A-1
Temperature
Inverse distance from contacts
B4
B3
1.0
0.5
0.0
Signal 2
Signal 1




```
Signal importance (high->low): [1, 3, 5, 4, 2]
┌ Info: Number of signals: 5
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:144
┌ Info: Locations (signals=5)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:148
┌ Warning: type Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.F
loat64,Core.Int64} not present in workspace; reconstructing
└ @ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
┌ Info: Robust k-means analysis results are loaded from file results-set0
0-v9-inv-750-1000-daln/Hmatrix-5-5_47-1000.jld!
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
```

```
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: type Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.F
loat64,Core.Int64} not present in workspace; reconstructing
└ @ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
┌ Info: Robust k-means analysis results are loaded from file results-set0
0-v9-inv-750-1000-daln/Wmatrix-5-5_14-1000.jld!
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
```

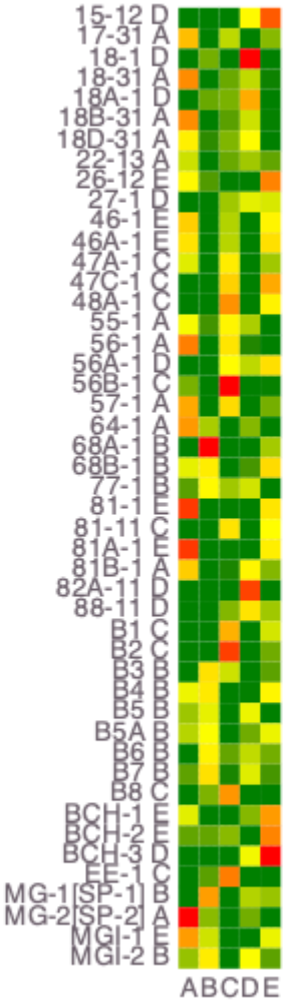
```
11×2 Array{Any,2}:
 "MG-2(SP-2)"  1.0
 "56-1"        0.833071
 "18-31"       0.803582
 "18B-31"      0.79762
 "64-1"        0.771609
 "57-1"        0.731212
 "17-31"       0.675958
 "81B-1"       0.638129
 "18D-31"      0.542359
 "55-1"        0.482608
 "22-13"       0.384279
```

```
11×2 Array{Any,2}:
 "68A-1"       1.0
 "MG-1(SP-1)"  0.760228
 "B7"          0.583165
 "B3"          0.579901
 "B4"          0.559561
 "MGI-2"       0.550751
 "68B-1"       0.549639
 "B6"          0.533677
 "77-1"        0.51494
 "B5A"         0.492662
 "B5"          0.444441
```

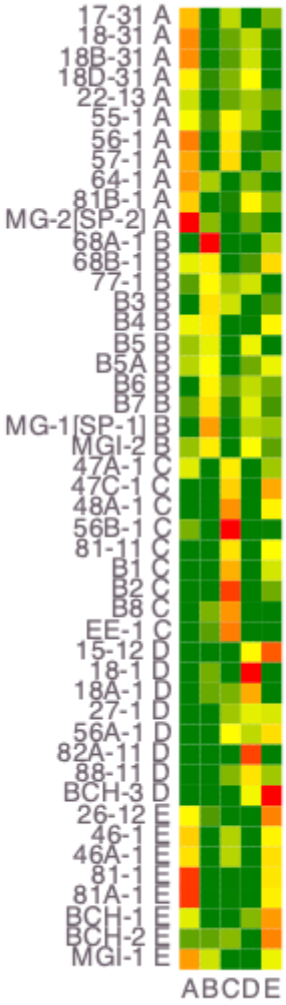
```
9×2 Array{Any,2}:
 "56B-1"  1.0
 "B2"     0.952516
 "EE-1"   0.837563
 "48A-1"  0.787595
 "B8"     0.779397
 "B1"     0.711321
 "47C-1"  0.625562
 "81-11"  0.574423
 "47A-1"  0.549964
```

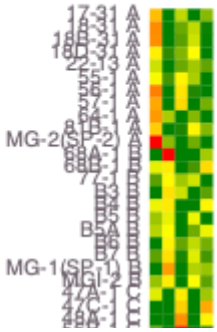
```
8×2 Array{Any,2}:
 "18-1"    1.0
 "82A-11"  0.947022
 "18A-1"   0.723864
 "88-11"   0.57605
 "15-12"   0.515703
 "BCH-3"   0.472471
```

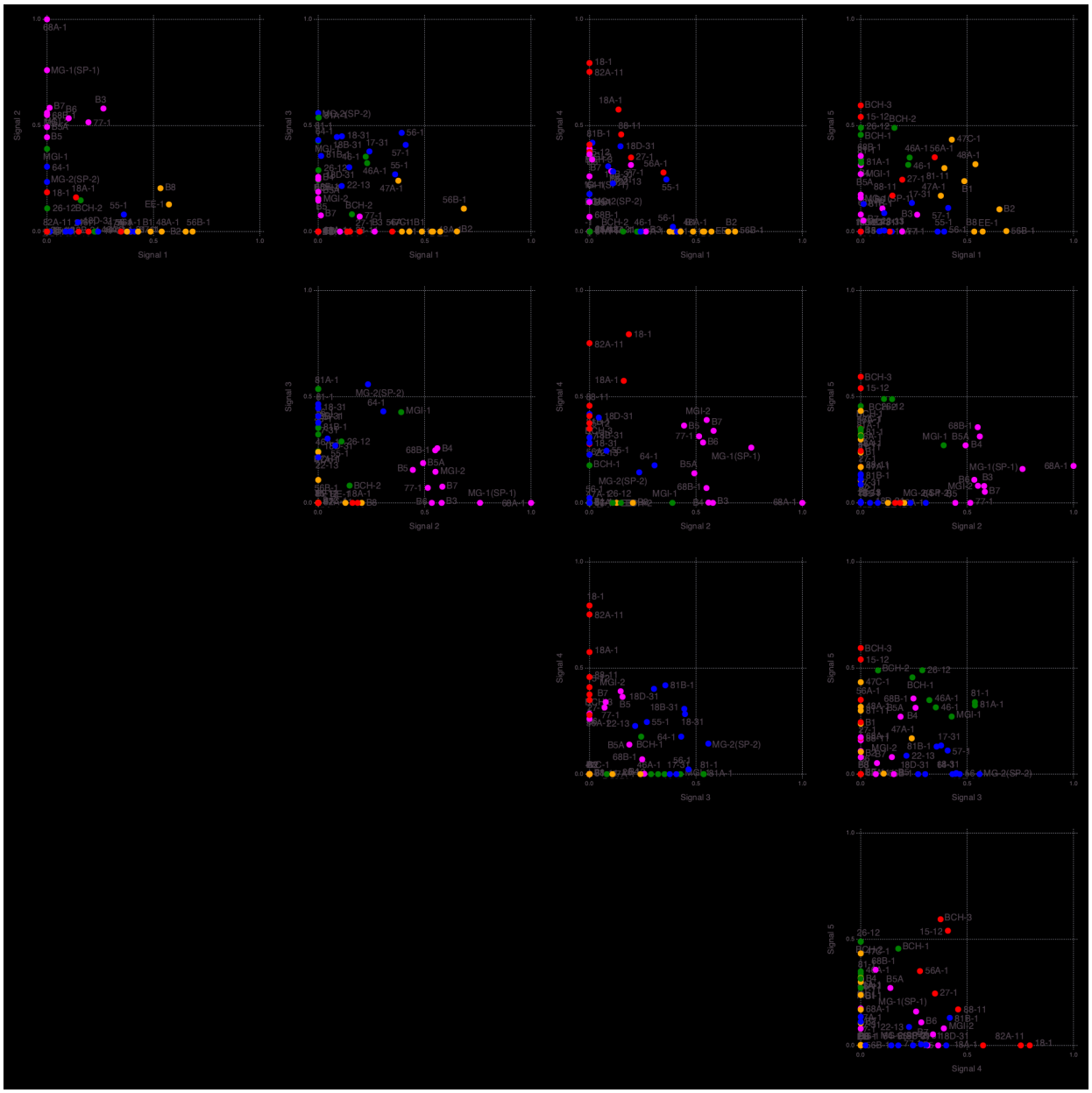
```
 "27-1"    0.439353

8×2 Array{Any,2}:
 "26-12"  0.82344
 "BCH-2"  0.822391
 "BCH-1"  0.766974
 "46A-1"  0.586862
 "81-1"   0.570404
 "81A-1"  0.545145
 "46-1"   0.529248
 "MGI-1"  0.456212
```

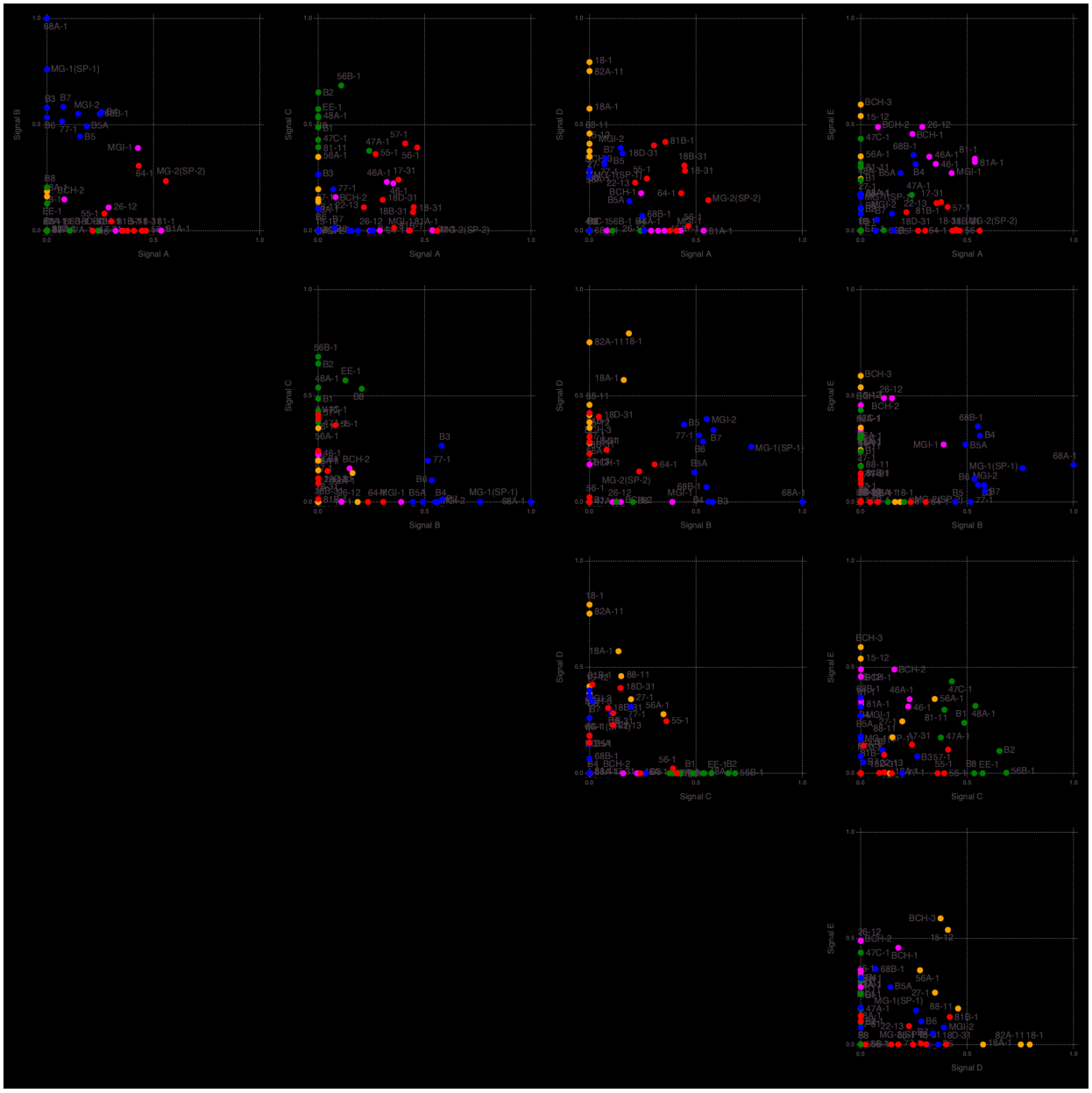


```
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Info: Signal A -> A Count: 11
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal B -> B Count: 11
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal C -> C Count: 9
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal D -> D Count: 8
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal E -> E Count: 8
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal A (S3) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
┌ Info: Signal B (S2) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
┌ Info: Signal C (S1) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
┌ Info: Signal D (S4) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
┌ Info: Signal E (S5) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
```

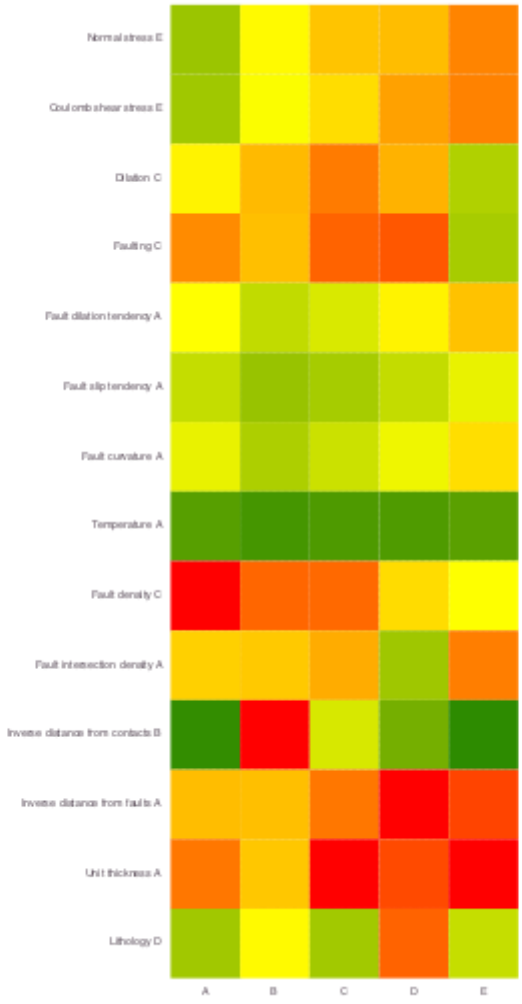

17-31 A
18-31 A
18B-31 A
18D-31 A
22-13 A
55-1 A
56-1 A
57-1 A
64-1 A
81B-1 A
MG-2[SP-2] A
68A-1 B
68B-1 B
77-1 B
B3 B
B4 B
B5 B
B5A B
B6 B
B7 B
MG-1[SP-1] B
MGI-2 B
47A-1 C
47C-1 C
48A-1 C
56B-1 C
81-11 C
B1 C
B2 C
B8 C
EE-1 C
15-12 D
18-1 D
18A-1 D
27-1 D
56A-1 D
82A-11 D
88-11 D
BCH-3 D
26-12 E
46-1 E
46A-1 E
81-1 E
81A-1 E
BCH-1 E
BCH-2 E
MGI-1 E
A B C D E


MG-2(SP-2)
MG-1(SP-1)


Signal 1
Signal 2
Signal 3
Signal 4
Signal 5

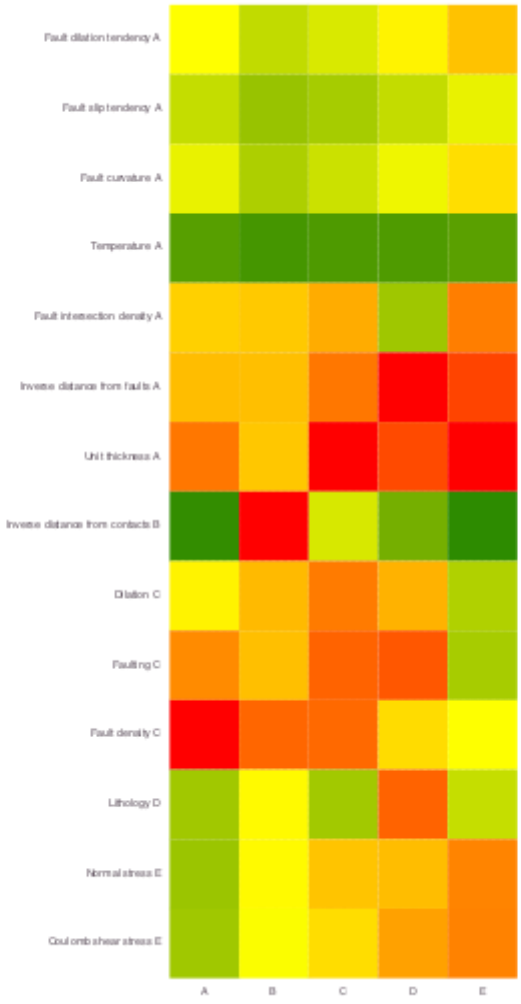

Signal A
Signal B
Signal C
Signal D
Signal E

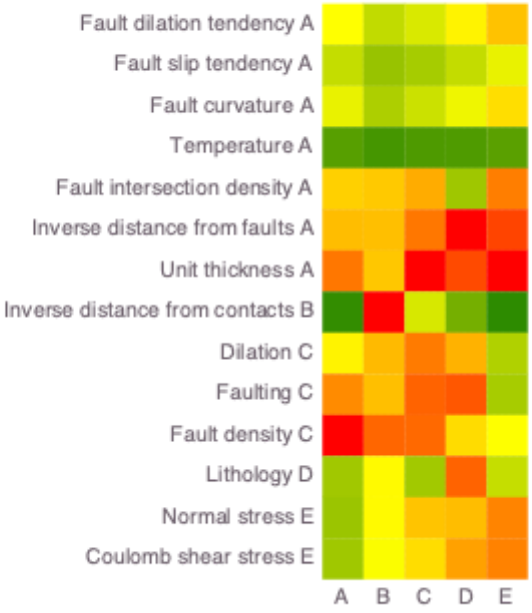
```
7×2 Array{Any,2}:
 "Unit thickness"                0.849937
 "Inverse distance from faults"  0.680541
 "Fault intersection density"    0.629292
 "Fault dilation tendency"       0.501789
 "Fault curvature"               0.449738
 "Fault slip tendency"           0.365781
 "Temperature"                   0.123165

1×2 Array{Any,2}:
 "Inverse distance from contacts"  1.0

3×2 Array{Any,2}:
 "Faulting"       0.892846
 "Fault density"  0.880551
 "Dilation"       0.841464

1×2 Array{Any,2}:
 "Lithology"  0.89235

2×2 Array{Any,2}:
 "Coulomb shear stress"  0.826886
 "Normal stress"         0.820471
```

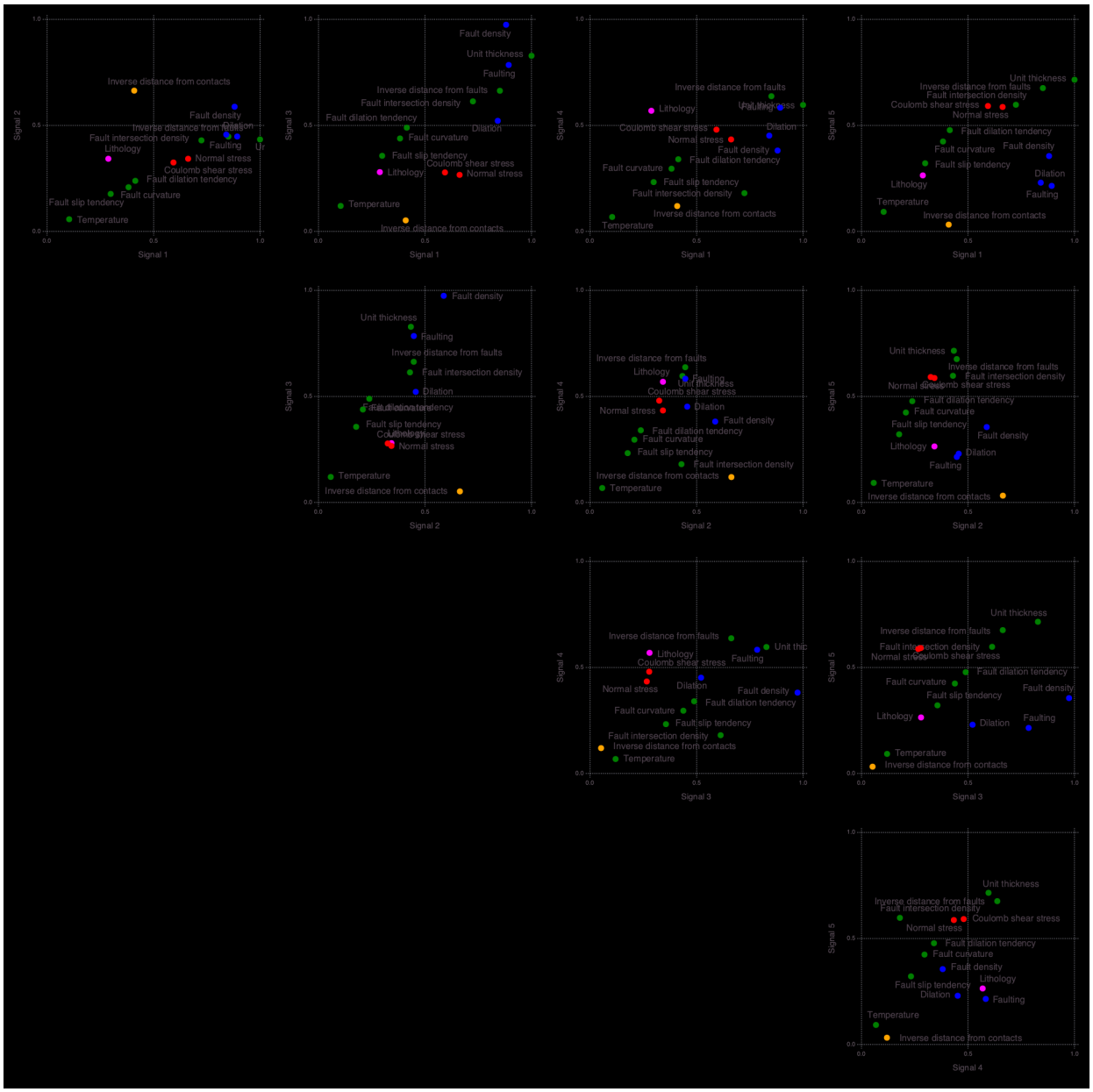


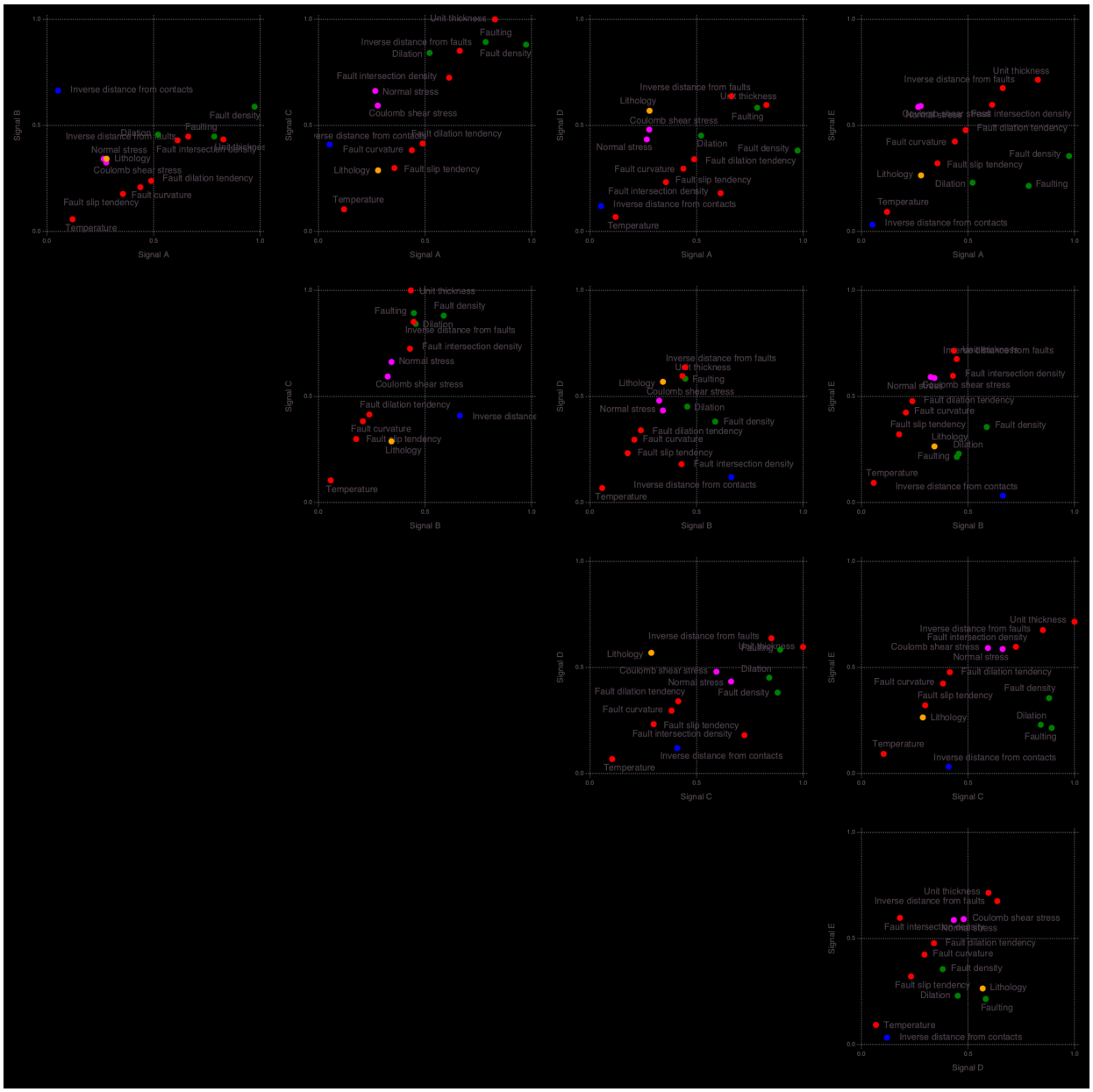

```
[ Info: Attributes (signals=5)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:322
[ Info: Signal A (S3) Count: 7
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
```

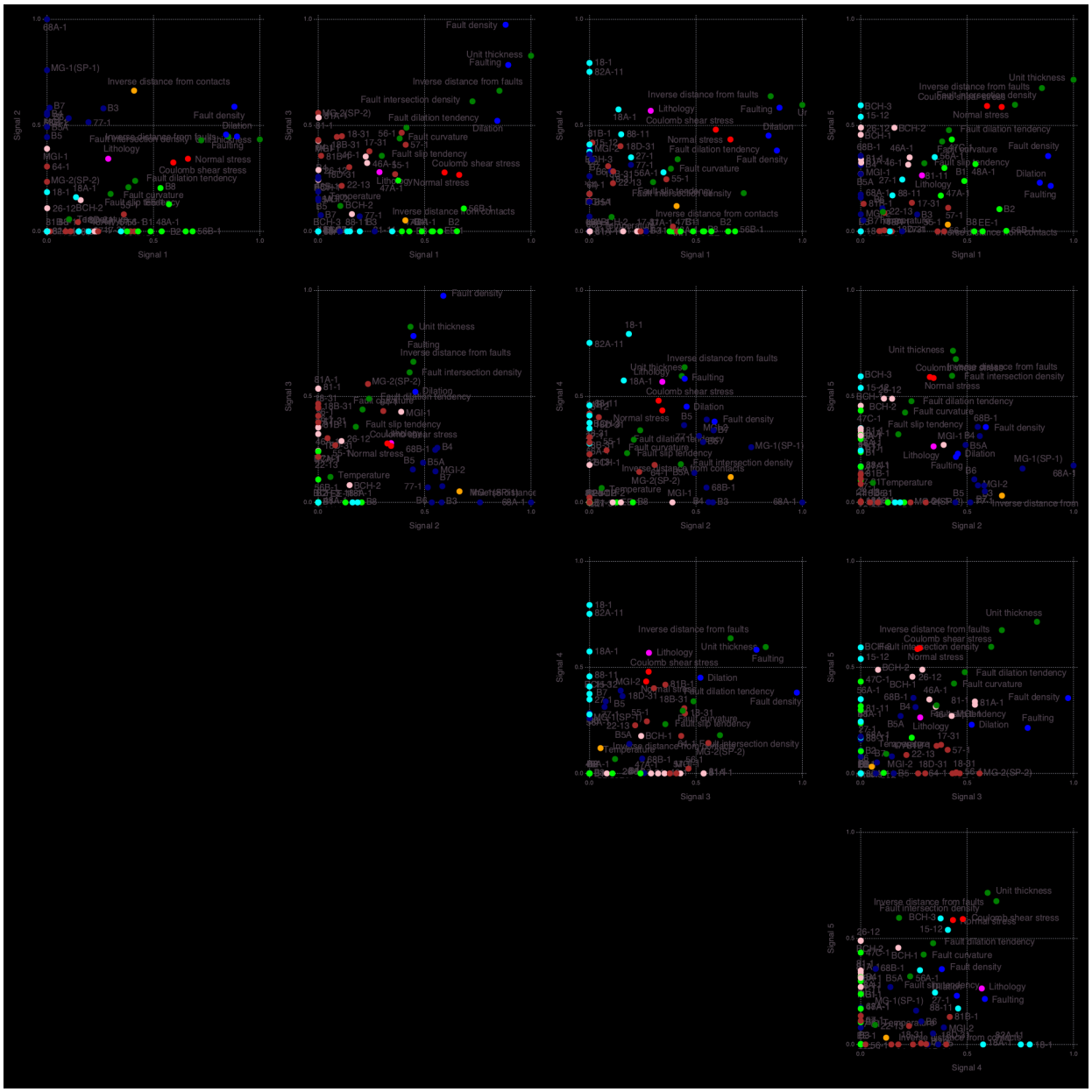
```
[ Info: Signal B (S1) Count: 3
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal C (S5) Count: 2
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal D (S2) Count: 1
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal E (S4) Count: 1
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal A -> A Count: 7
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal D -> B Count: 1
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal B -> C Count: 3
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal E -> D Count: 1
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal C -> E Count: 2
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal A (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
[ Info: Signal B (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
[ Info: Signal C (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
[ Info: Signal D (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
[ Info: Signal E (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
```

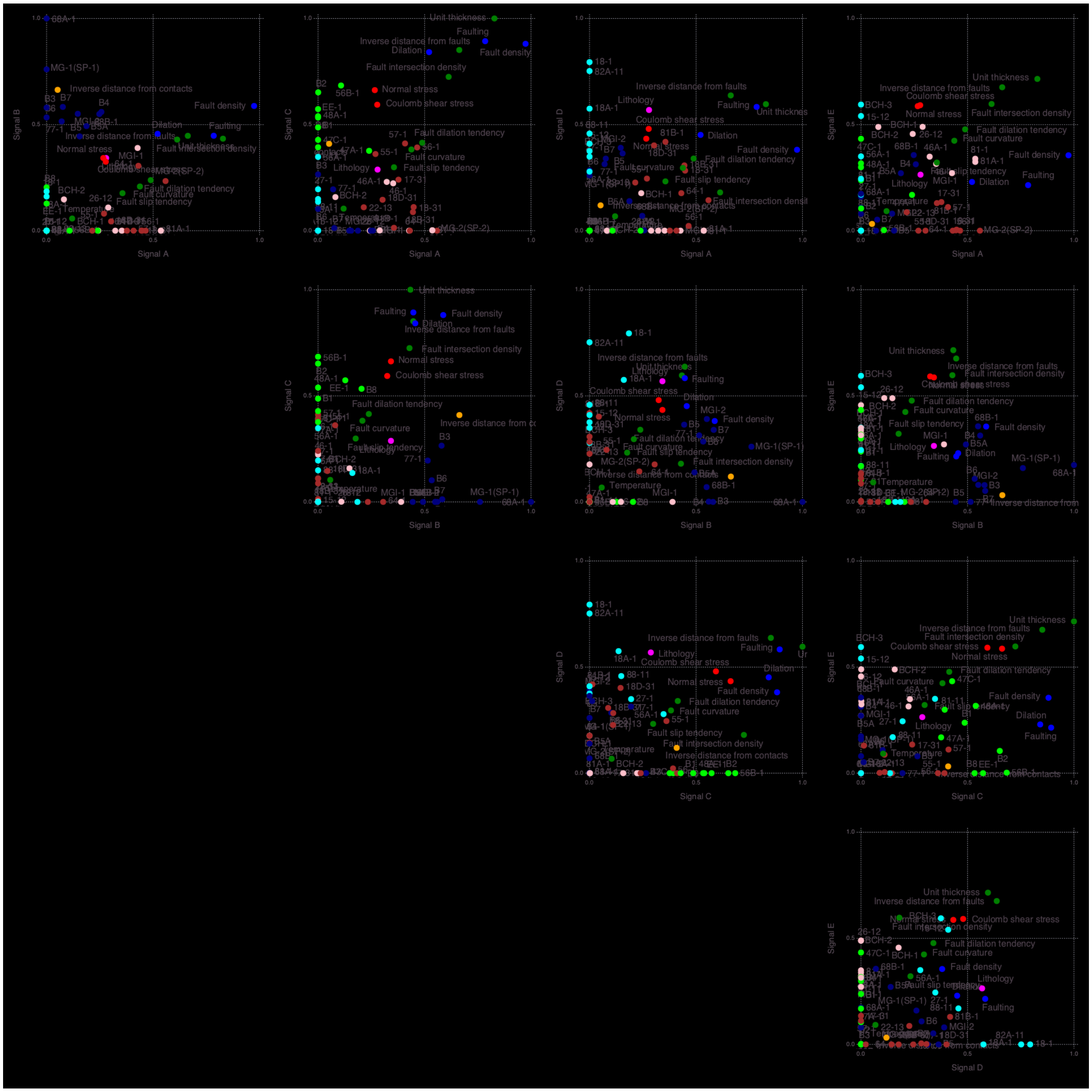

Fault dilation tendency A
Fault slip tendency A
Fault curvature A
Temperature A
Fault intersection density A
Inverse distance from faults A
Unit thickness A
Inverse distance from contacts B
Dilation C
Faulting C
Fault density C
Lithology D
Normal stress E
Coulomb shear stress E
A
B
C
D
E


Fault dilation tendency A
Fault slip tendency A
Fault curvature A
Temperature A
Fault intersection density A
Inverse distance from faults A
Unit thickness A
Inverse distance from contacts B
Dilation C
Faulting C
Fault density C
Lithology D
Normal stress E
Coulomb shear stress E
A
B
C
D
E


Signal 1
Signal 2
Signal 3
Signal 4
Signal 5
Inverse distance from contacts
Fault density
Unit thickness
Faulting
Inverse distance from faults
Fault intersection density
Fault dilation tendency
Dilation
Fault curvature
Fault slip tendency
Coulomb shear stress
Lithology
Normal stress
Temperature


Signal A
Signal B
Signal C
Signal D
Signal E
Inverse distance from contacts
Fault density
Faulting
Dilation
Inverse distance from faults
Normal stress
Fault intersection density
Lithology
Coulomb shear stress
Fault dilation tendency
Fault curvature
Fault slip tendency
Temperature
Unit thickness

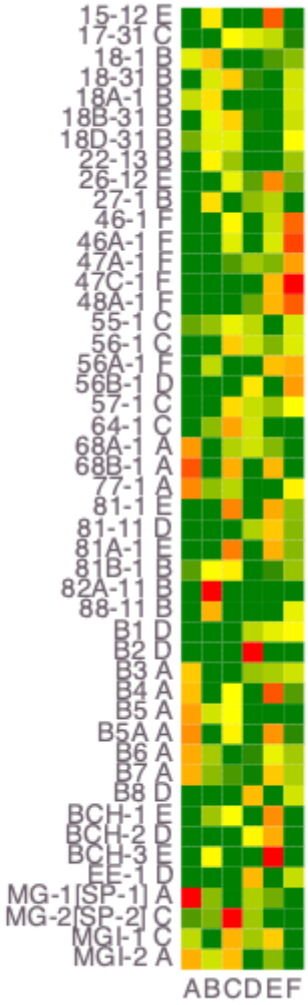

Signal 1
Signal 2
Signal 3
Signal 4
Signal 5
Fault density
Unit thickness
Faulting
Inverse distance from faults
Fault intersection density
Fault dilation tendency
Dilation
Fault curvature
Fault slip tendency
Coulomb shear stress
Normal stress
Lithology
Inverse distance from contacts
Temperature
MG-1(SP-1)
MG-2(SP-2)
MGI-1
MGI-2
68A-1
18-1
82A-11
18A-1
88-11
27-1
77-1
55-1
56A-1
18D-31
18B-31
17-31
22-13
57-1
68B-1
47A-1
B1
B2
B3
B4
B5
B5A
B6
B7
B8
BCH-1
BCH-2
BCH-3
15-12
26-12
47C-1
46A-1
81A-1
81B-1
81-1
Inverse distance from
Coulomb shear stress



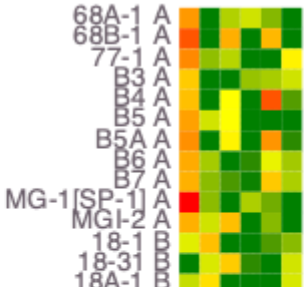
```
Signal importance (high->low): [1, 5, 2, 6, 4, 3]
┌ Info: Number of signals: 6
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:144
┌ Info: Locations (signals=6)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:148
┌ Warning: type Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.F
loat64,Core.Int64} not present in workspace; reconstructing
└ @ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
┌ Info: Robust k-means analysis results are loaded from file results-set0
0-v9-inv-750-1000-daln/Hmatrix-6-6_47-1000.jld!
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: type Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.F
loat64,Core.Int64} not present in workspace; reconstructing
└ @ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
```

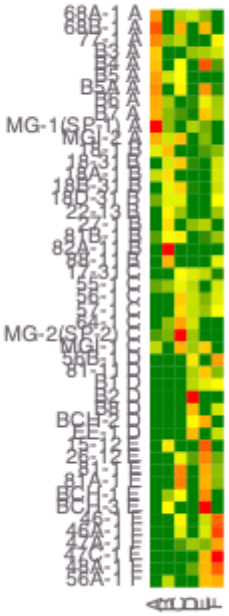
```
11×2 Array{Any,2}:
 "MG-1(SP-1)"  1.0
 "68B-1"       0.917059
 "77-1"        0.81018
 "B5A"         0.794163
 "68A-1"       0.771571
 "B5"          0.751175
 "B6"          0.726543
 "MGI-2"       0.712331
 "B7"          0.71064
 "B4"          0.671091
 "B3"          0.643308

10×2 Array{Any,2}:
 "82A-11"  1.0
 "88-11"   0.708797
 "18-1"    0.670833
 "27-1"    0.588465
 "18A-1"   0.586851
 "22-13"   0.530055
 "81B-1"   0.490522
 "18B-31"  0.450915
 "18D-31"  0.439487
 "18-31"   0.413683


7×2 Array{Any,2}:
 "MG-2(SP-2)"  1.0
 "64-1"        0.741999
 "MGI-1"       0.701663
 "56-1"        0.640372
 "57-1"        0.600702
 "17-31"       0.512659
 "55-1"        0.453248

7×2 Array{Any,2}:
 "B2"     1.0
 "EE-1"   0.68867
 "B8"     0.679526
 "56B-1"  0.56822
 "BCH-2"  0.521776
 "B1"     0.342468
 "81-11"  0.320946

6×2 Array{Any,2}:
 "BCH-3"  1.0
 "15-12"  0.904396
 "26-12"  0.808831
 "BCH-1"  0.795303
 "81-1"   0.7272
 "81A-1"  0.707665

6×2 Array{Any,2}:
 "47C-1"  1.0
 "46A-1"  0.943298
 "48A-1"  0.903309
 "46-1"   0.882457
```

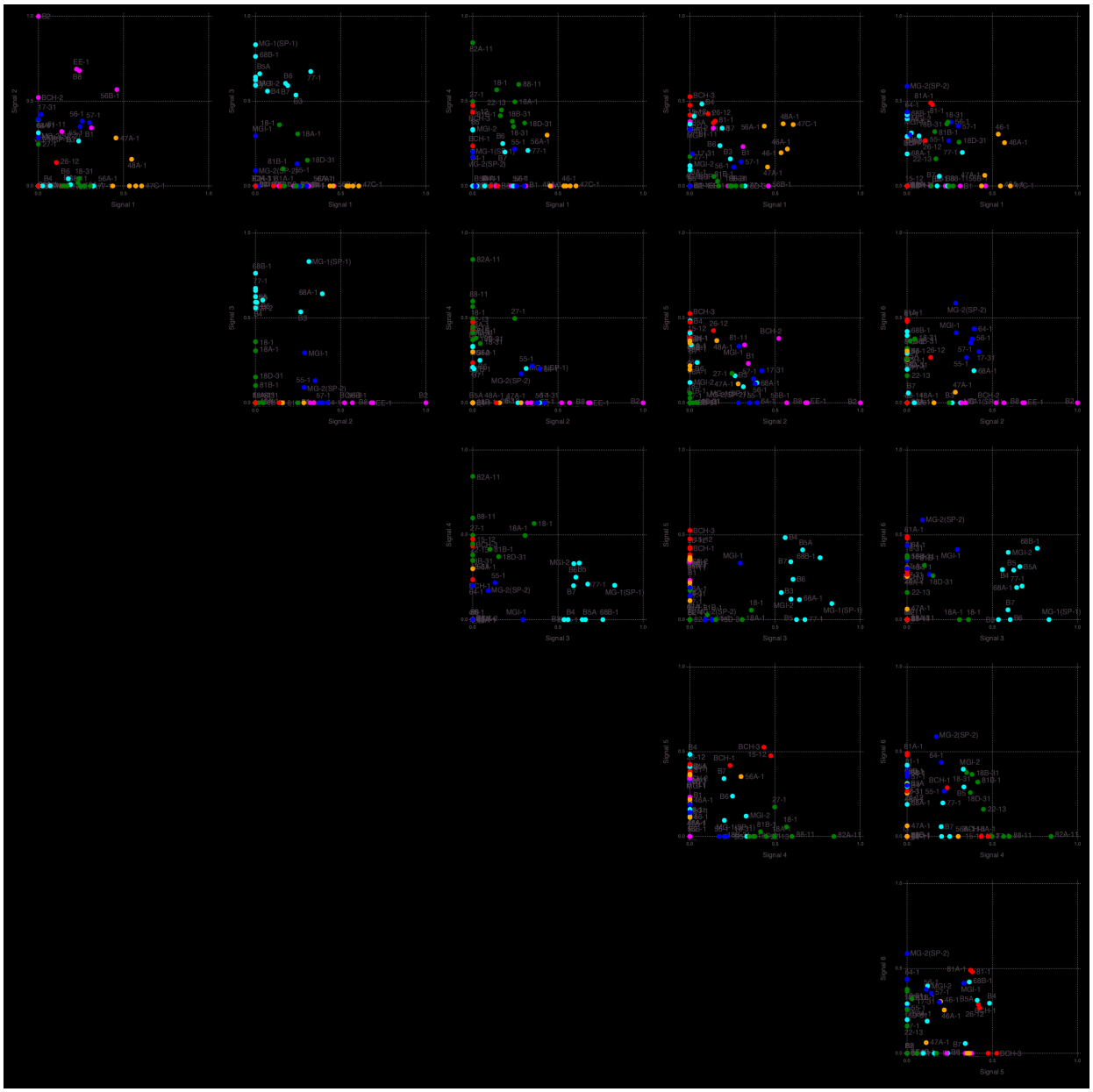
```
"47A-1"  0.751523
```

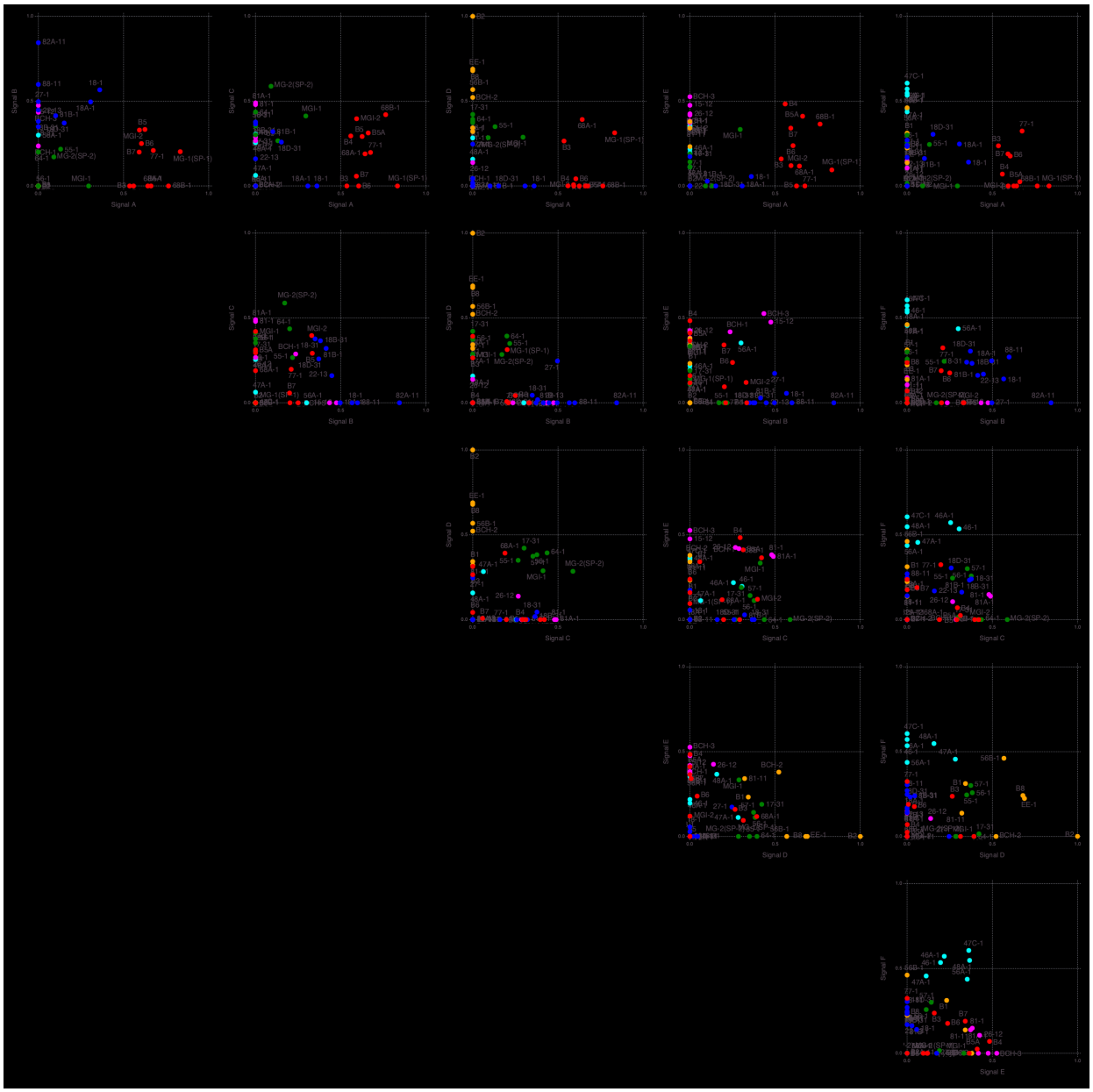


```
┌ Info: Robust k-means analysis results are loaded from file results-set0
0-v9-inv-750-1000-daln/Wmatrix-6-6_14-1000.jld!
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Info: Signal A -> A Count: 11
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal B -> B Count: 10
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal C -> C Count: 7
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal D -> D Count: 7
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal E -> E Count: 6
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal F -> F Count: 6
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal A (S3) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
┌ Info: Signal B (S4) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
┌ Info: Signal C (S6) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
┌ Info: Signal D (S2) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
┌ Info: Signal E (S5) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
┌ Info: Signal F (S1) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
```


68A-1 A
68B-1 A
77-1 A
B3 A
B4 A
B5 A
B5A A
B6 A
B7 A
MG-1[SP-1] A
MGI-2 A
18-1 B
18-31 B

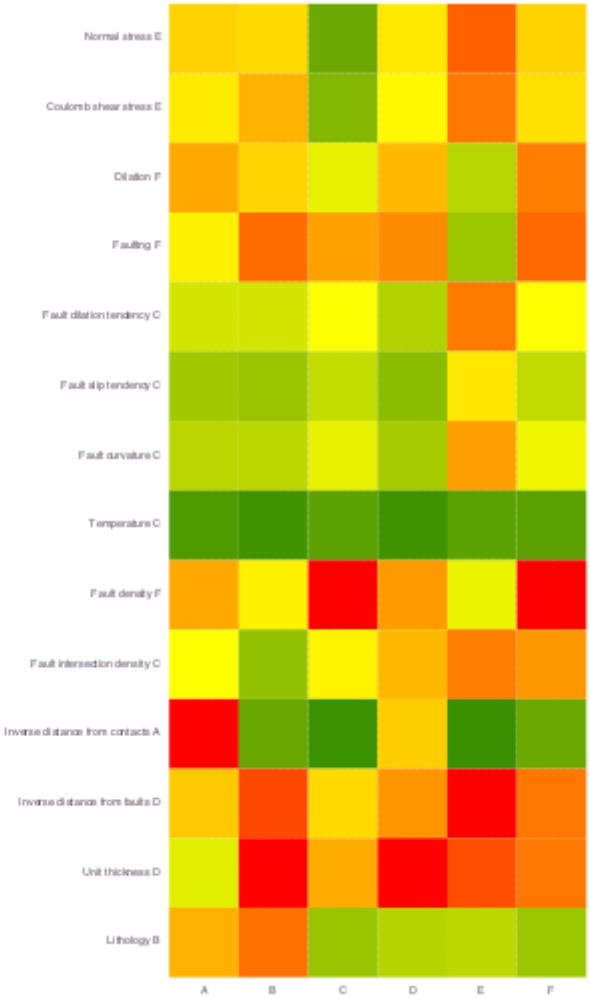

68A-1 A
MG-1(SP-1) A
MG-2(SP-2)





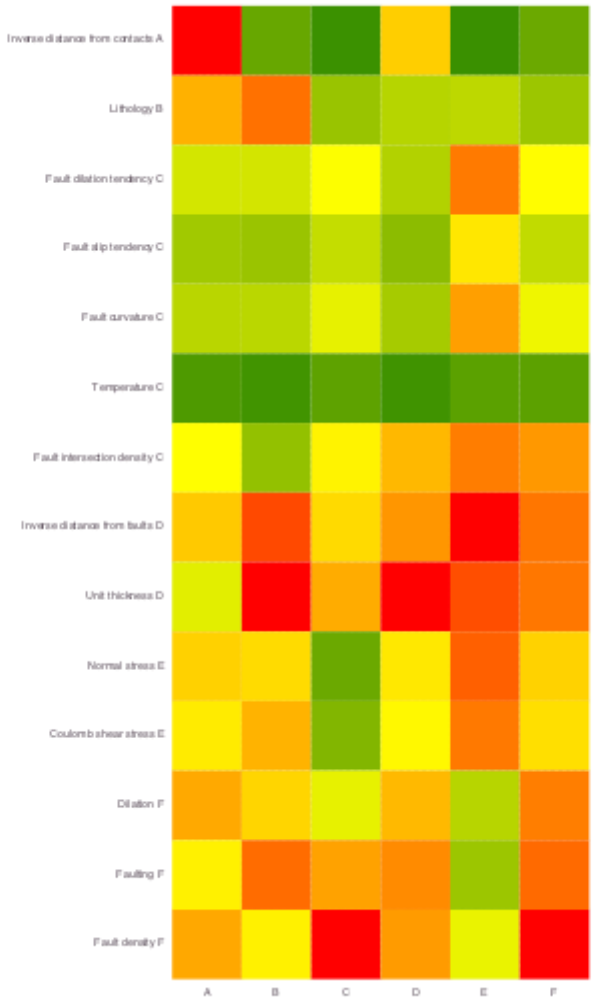
```
1×2 Array{Any,2}:
 "Inverse distance from contacts"  1.0

1×2 Array{Any,2}:
 "Lithology"  0.864227

5×2 Array{Any,2}:
 "Fault intersection density"  0.534767
 "Fault dilation tendency"     0.494983
 "Fault curvature"             0.444422
```

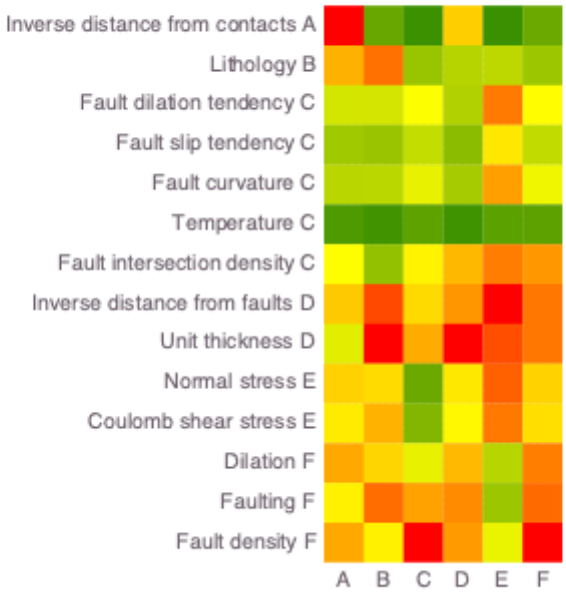
```
 "Fault slip tendency"          0.367193
 "Temperature"                  0.136511
2×2 Array{Any,2}:
 "Unit thickness"                 1.0
 "Inverse distance from faults"   0.778501

2×2 Array{Any,2}:
 "Normal stress"          0.896801
 "Coulomb shear stress"   0.845105

3×2 Array{Any,2}:
 "Fault density"  1.0
 "Faulting"       0.877916
 "Dilation"       0.834909
```

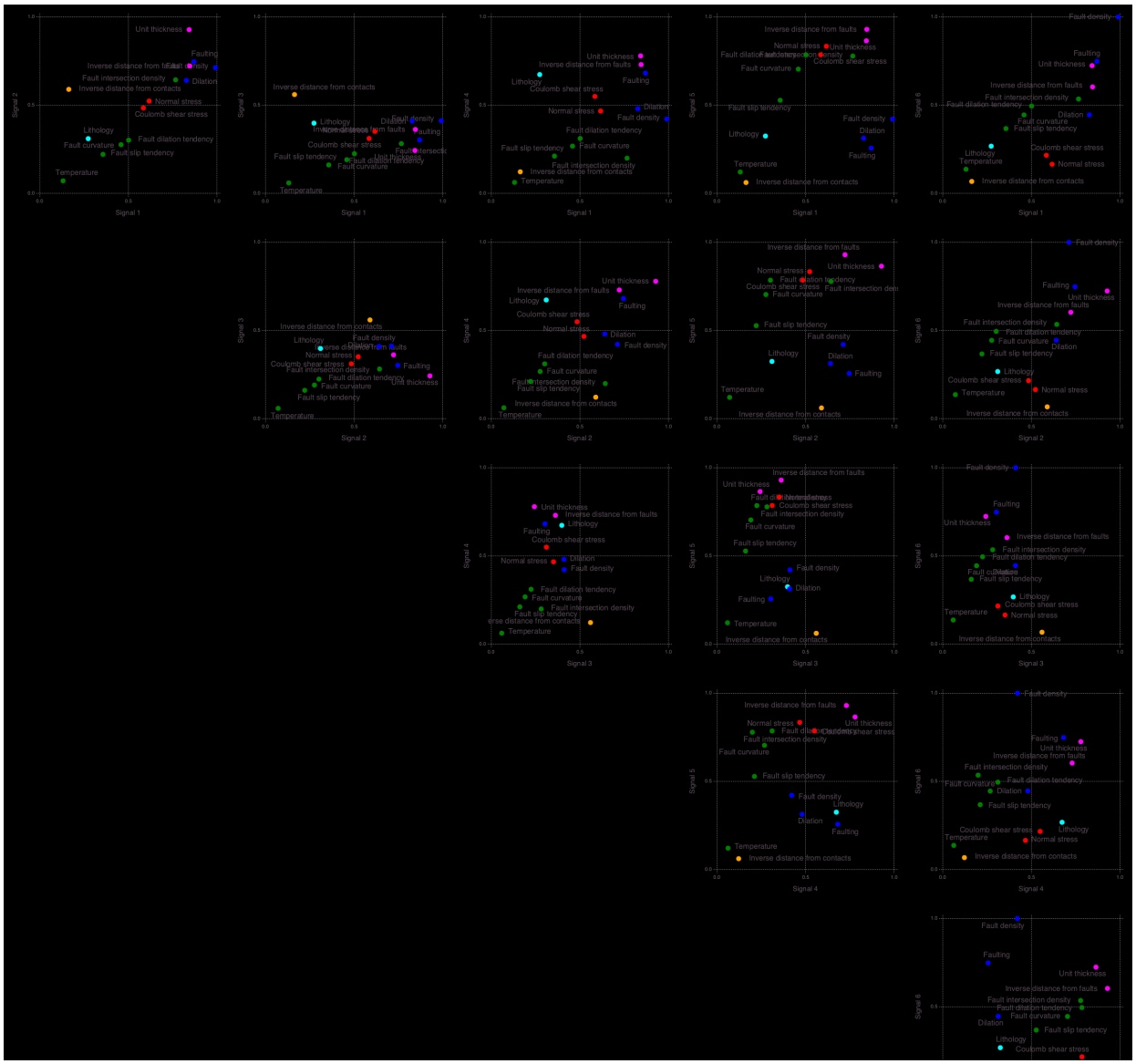


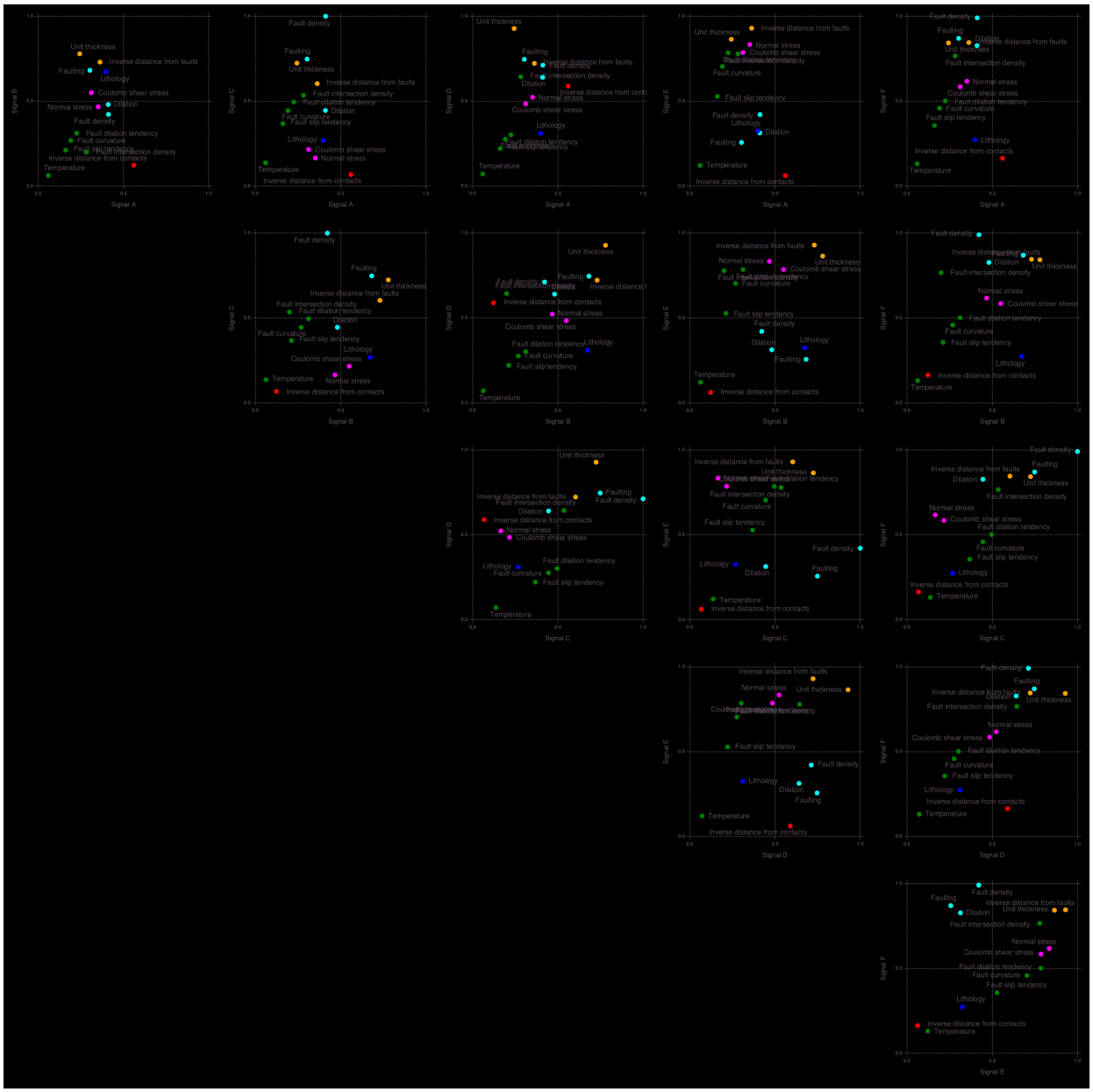
```
[ Info: Attributes (signals=6)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:322
[ Info: Signal A (S6) Count: 5
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal B (S1) Count: 3
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal C (S5) Count: 2
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal D (S2) Count: 2
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal E (S3) Count: 1
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal F (S4) Count: 1
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal E -> A Count: 1
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal F -> B Count: 1
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal A -> C Count: 5
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal D -> D Count: 2
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal C -> E Count: 2
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal B -> F Count: 3
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal A (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
[ Info: Signal B (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
[ Info: Signal C (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
[ Info: Signal D (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
[ Info: Signal E (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
```

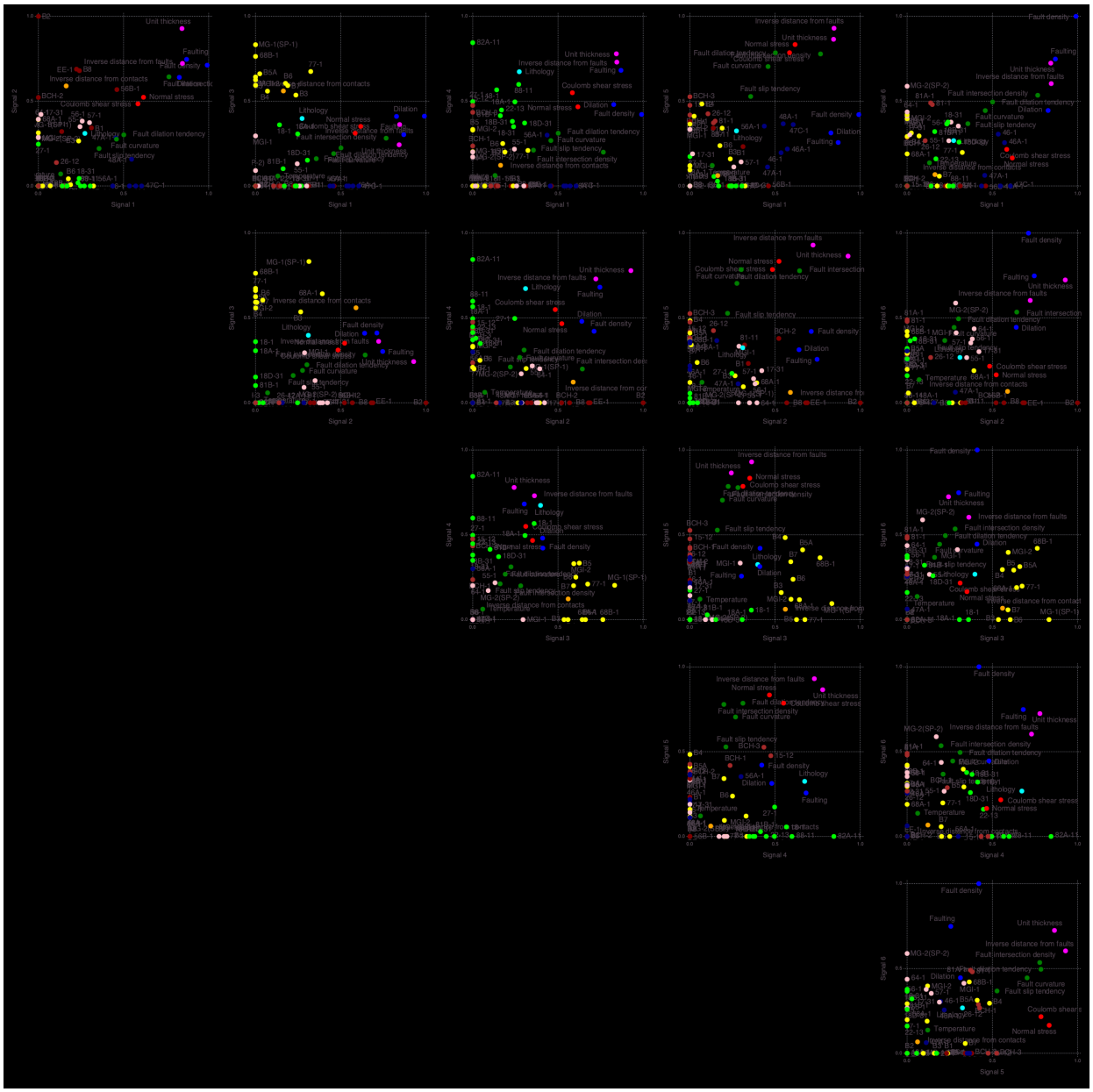
```
┌ Info: Signal F (remapped k-means clustering)
```

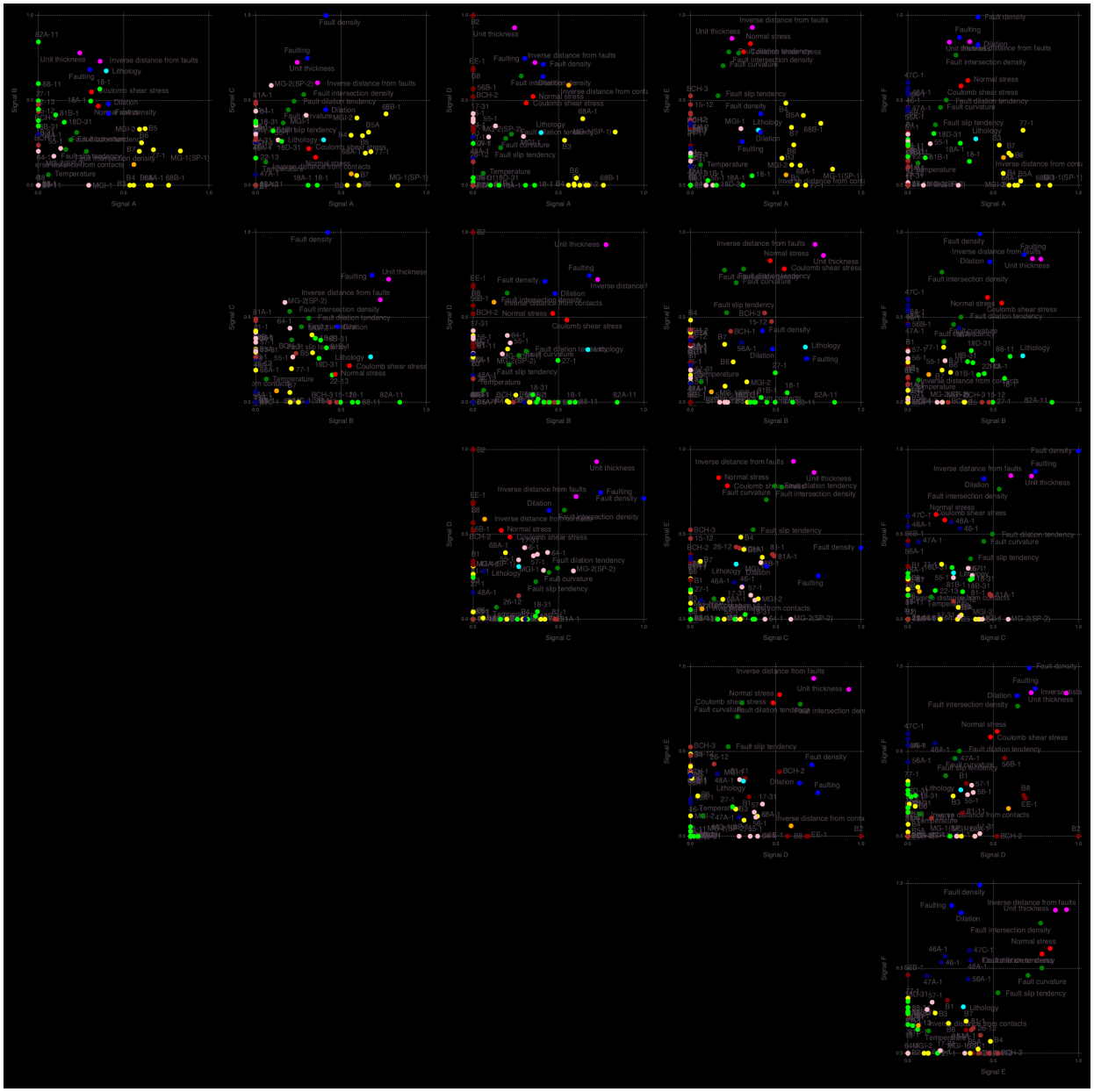



Inverse distance from contacts A
Lithology B
Fault dilation tendency C
Fault slip tendency C
Fault curvature C
Temperature C
Fault intersection density C
Inverse distance from faults D
Unit thickness D
Normal stress E
Coulomb shear stress E
Dilation F
Faulting F
Fault density F
A B C D E F


Unit thickness
Faulting
Inverse distance from faults
Fault density
Fault intersection density
Dilation
Inverse distance from contacts
Normal stress
Coulomb shear stress
Lithology
Fault curvature
Fault dilation tendency
Fault slip tendency
Temperature
Signal 1
Signal 2
Signal 3
Signal 4
Signal 5
Signal 6


Signal A
Signal B
Signal C
Signal D
Signal E
Signal F
Unit thickness
Inverse distance from faults
Faulting
Lithology
Coulomb shear stress
Normal stress
Dilation
Fault density
Fault dilation tendency
Fault curvature
Fault slip tendency
Fault intersection density
Inverse distance from contacts
Temperature





Out[62]: ([[1, 2], [3, 2, 1, 4, 5], [3, 4, 6, 2, 5, 1]], [['B', 'B', 'B', 'B',

```
'B', 'B', 'B', 'B', 'B', 'B', 'A', 'B', 'B', 'B'], ['E', 'E', 'C', 'C',
'A', 'A', 'A', 'A', 'C', 'A', 'B', 'A', 'A', 'D'], ['E', 'E', 'F', 'F',
'C', 'C', 'C', 'C', 'F', 'C', 'A', 'D', 'D', 'B']], [['B', 'A', 'A', 'B',
'A', 'B', 'B', 'A', 'B', 'B'  …  'A', 'A', 'B', 'B', 'B', 'A', 'A', 'A',
'A', 'A'], ['D', 'A', 'D', 'A', 'D', 'A', 'A', 'A', 'E', 'D'  …  'B',
'C', 'E', 'E', 'D', 'C', 'B', 'A', 'E', 'B'], ['E', 'C', 'B', 'B', 'B',
'B', 'B', 'B', 'E', 'B'  …  'A', 'D', 'E', 'D', 'E', 'D', 'A', 'C', 'C',
'A']])
```

Flatten the tensor into a matrix (type 2)

Matrix rows merge the depth and well locations dimensions.

Matrix cols represent the well attributes.

In [64]:
```
Xdlan = reshape(permutedims(Tn, (1,3,2)), ((depth * length(locations))), le
```

Perform NMFk analyses

Here the **NMFk** results are loaded from a prior ML runs.

In [65]:
```
W, H, fitquality, robustness, aic = NMFk.execute(Xdlan, nkrange, nruns; res
W, H, fitquality, robustness, aic = NMFk.load(nkrange, nruns; resultdir=res
```

```
Signals:  2 Fit:     8717.101 Silhouette:    0.9918721 AIC:     -1087260
Signals:  3 Fit:     6319.428 Silhouette:    0.5782437 AIC:     -1124899
Signals:  4 Fit:     4843.099 Silhouette:   -0.2086358 AIC:     -1143846
Signals:  5 Fit:     3526.994 Silhouette:   0.03306949 AIC:     -1179956
Signals:  6 Fit:     2430.352 Silhouette:   -0.5717948 AIC:     -1234661
Signals:  7 Fit:     1649.869 Silhouette:   -0.4817311 AIC:     -1294388
Signals:  8 Fit:     1182.794 Silhouette:    0.1610176 AIC:     -1335780
Signals:  2 Fit:     8717.101 Silhouette:    0.9918721 AIC:     -1087260
Signals:  3 Fit:     6319.428 Silhouette:    0.5782437 AIC:     -1124899
Signals:  4 Fit:     4843.099 Silhouette:   -0.2086358 AIC:     -1143846
Signals:  5 Fit:     3526.994 Silhouette:   0.03306949 AIC:     -1179956
Signals:  6 Fit:     2430.352 Silhouette:   -0.5717948 AIC:     -1234661
Signals:  7 Fit:     1649.869 Silhouette:   -0.4817311 AIC:     -1294388
Signals:  8 Fit:     1182.794 Silhouette:    0.1610176 AIC:     -1335780
Signals:  2 Fit:     8717.101 Silhouette:    0.9918721 AIC:     -1087260
Signals:  3 Fit:     6319.428 Silhouette:    0.5782437 AIC:     -1124899
Signals:  4 Fit:     4843.099 Silhouette:   -0.2086358 AIC:     -1143846
Signals:  5 Fit:     3526.994 Silhouette:   0.03306949 AIC:     -1179956
Signals:  6 Fit:     2430.352 Silhouette:   -0.5717948 AIC:     -1234661
Signals:  7 Fit:     1649.869 Silhouette:   -0.4817311 AIC:     -1294388
Signals:  8 Fit:     1182.794 Silhouette:    0.1610176 AIC:     -1335780
┌ Info: Results
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkExecute.jl:15
┌ Info: Optimal solution: 3 signals
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkExecute.jl:20
┌ Info: Optimal solution: 3 signals
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkIO.jl:30
```

As seen from the output the ML analyses identified that the optimal number of geothermal signatures in the dataset **3**.

Solutions with a number of signatures less than **3** are underfitting.

Solutions with a number of signatures greater than **3** are overfitting and unacceptable.

The set of accetable solutions are defined as follows:

In [66]:
```
NMFk.getks(nkrange, robustness[nkrange])
```

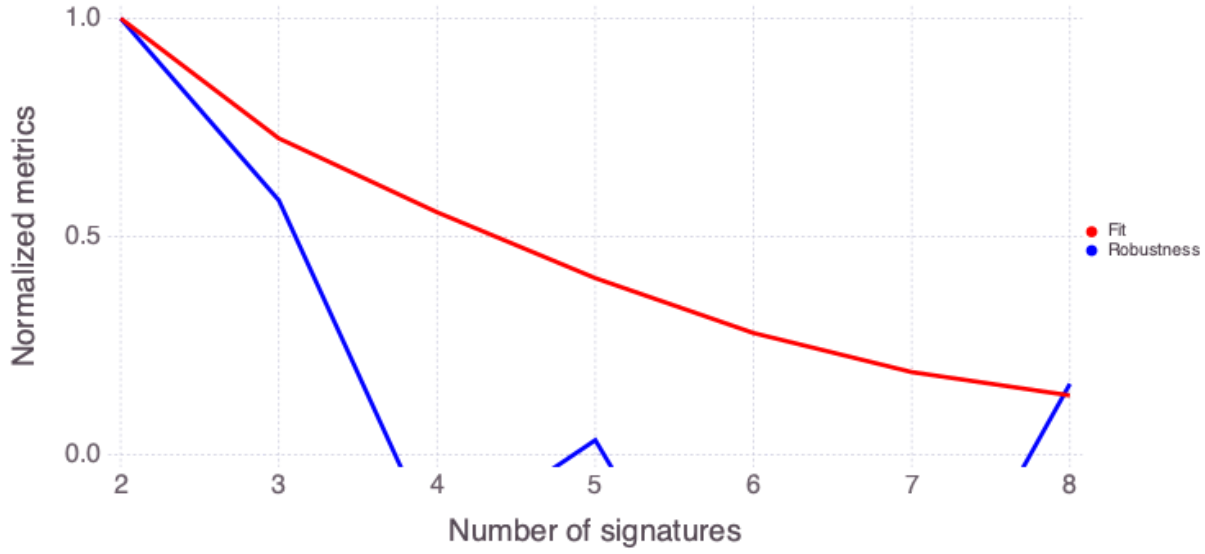
Out[66]:
```
2-element Array{Int64,1}:
 2
 3
```

The accceptable solutions contain 2 and 3 signatures.

Plot results

Plot representing solution quality (fit) and silhouette width (robistness) for different number of sigantures `k` :

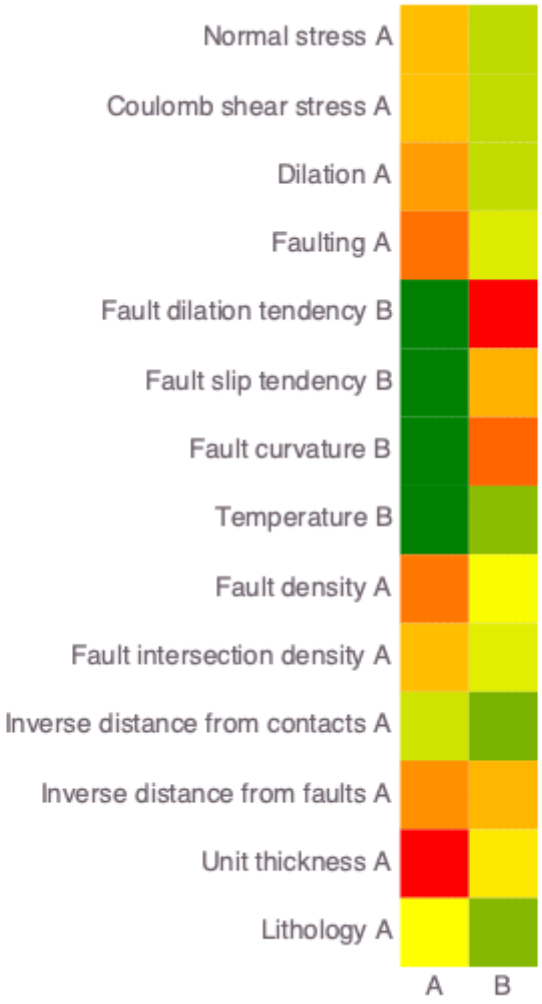
In [68]:
```
NMFk.plot_signal_selecton(nkrange, fitquality, robustness; figuredir="$figu
```



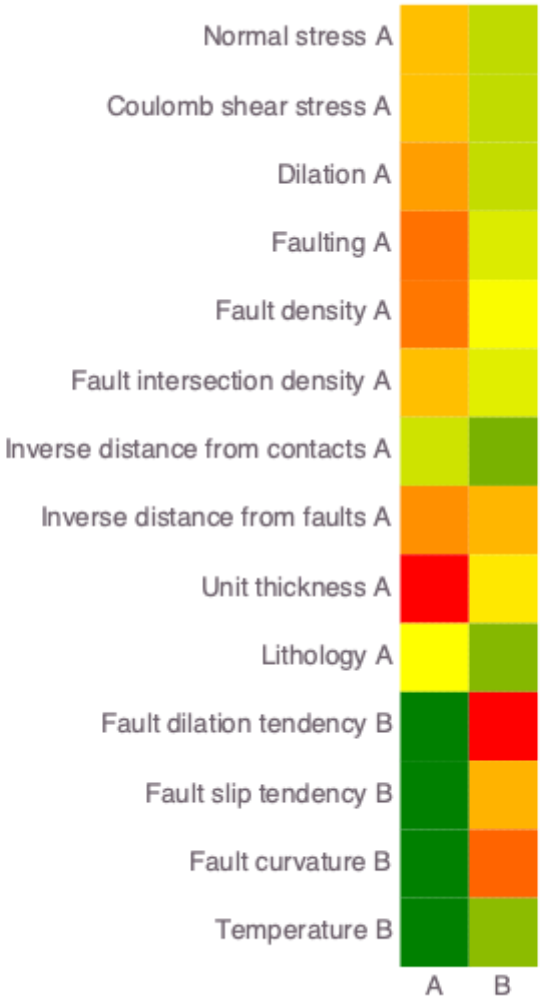
The ML solutions containing 2 and 3 signatures are further analyzed as follows:

In [69]:
```
NMFk.clusterresults(NMFk.getks(nkrange, robustness[nkrange]), W, H, locatio
```

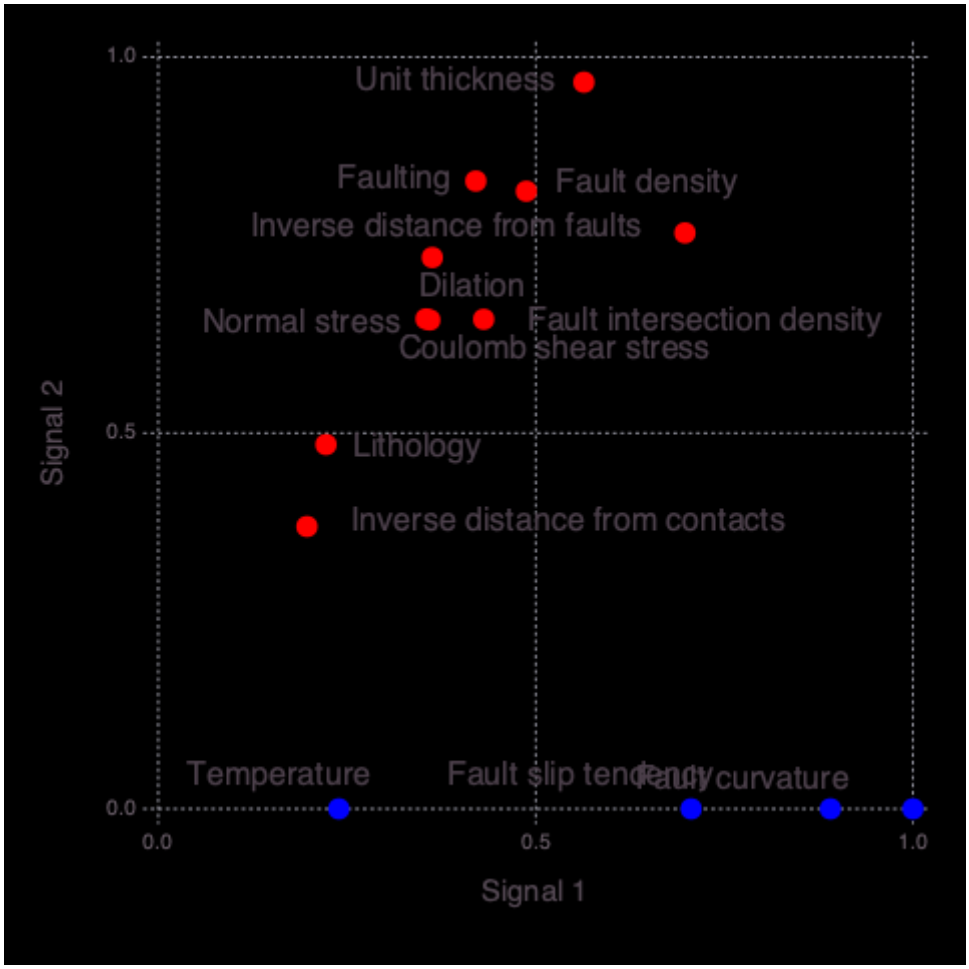
```
Signal importance (high->low): [2, 1]
┌ Info: Number of signals: 2
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:144
┌ Info: Attributes (signals=2)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:148
┌ Warning: type Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.F
loat64,Core.Int64} not present in workspace; reconstructing
└ @ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
┌ Info: Robust k-means analysis results are loaded from file results-set0
0-v9-inv-750-1000-dlan/Hmatrix-2-2_14-1000.jld!
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: type Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.F
loat64,Core.Int64} not present in workspace; reconstructing
└ @ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697

10×2 Array{Any,2}:
 "Unit thickness"                 1.0
 "Faulting"                       0.863986
 "Fault density"                  0.849999
 "Inverse distance from faults"   0.792619
 "Dilation"                       0.75876
 "Normal stress"                  0.674322
 "Fault intersection density"     0.673763
 "Coulomb shear stress"           0.672813
 "Lithology"                      0.501336
 "Inverse distance from contacts" 0.388519

4×2 Array{Any,2}:
 "Fault dilation tendency"  1.0
 "Fault curvature"          0.89069
 "Fault slip tendency"      0.706146
 "Temperature"              0.239306
```

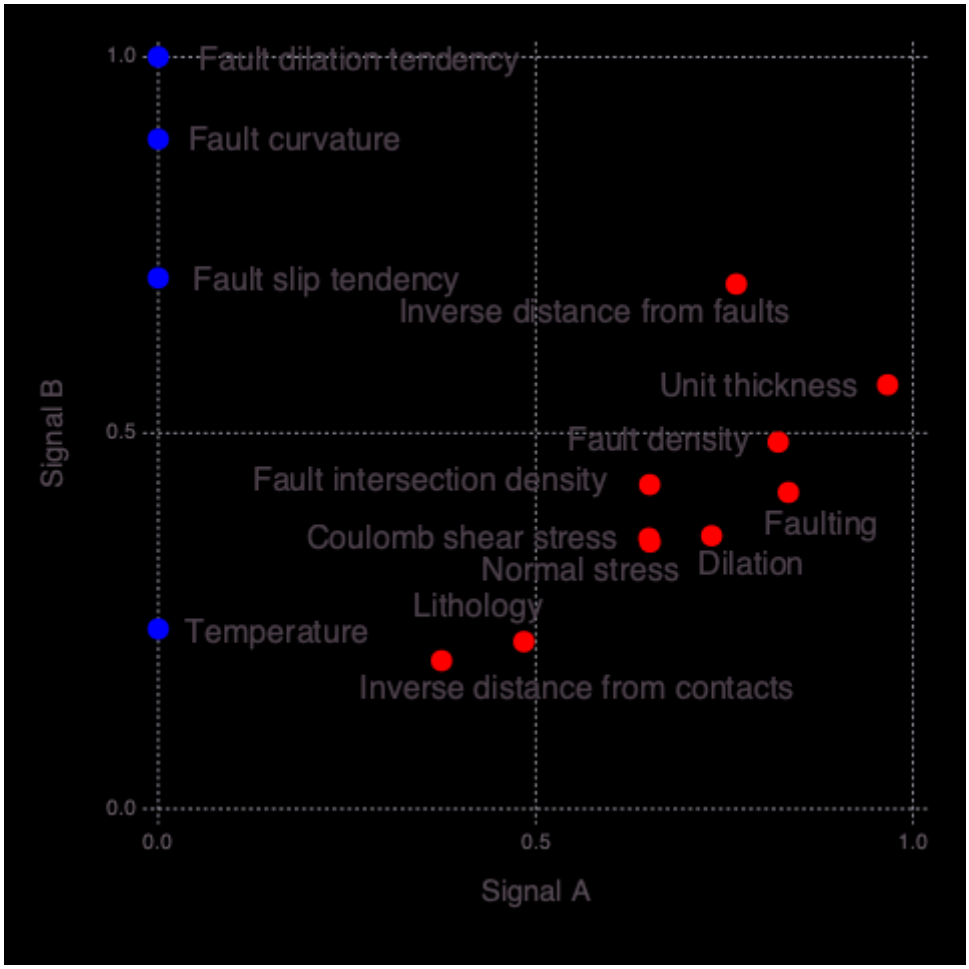



```
┌ Info: Robust k-means analysis results are loaded from file results-set0
0-v9-inv-750-1000-dlan/Wmatrix-2-2_47-1000.jld!
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
[ Info: Signal A -> A Count: 10
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
[ Info: Signal B -> B Count: 4
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
[ Info: Signal A (S2) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
[ Info: Signal B (S1) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
```


Normal stress A
Coulomb shear stress A
Dilation A
Faulting A
Fault density A
Fault intersection density A
Inverse distance from contacts A
Inverse distance from faults A
Unit thickness A
Lithology A
Fault dilation tendency B
Fault slip tendency B
Fault curvature B
Temperature B
A
B


Normal stress A
Coulomb shear stress A
Dilation A
Faulting A
Fault density A
Fault intersection density A
Inverse distance from contacts A
Inverse distance from faults A
Unit thickness A

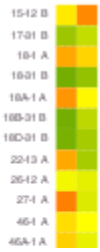

Unit thickness
Faulting
Fault density
Inverse distance from faults
Dilation
Normal stress
Fault intersection density
Coulomb shear stress
Lithology
Inverse distance from contacts
Temperature
Fault slip tendency
Fault curvature
1.0
0.5
0.0
0.0
0.5
1.0
Signal 2
Signal 1



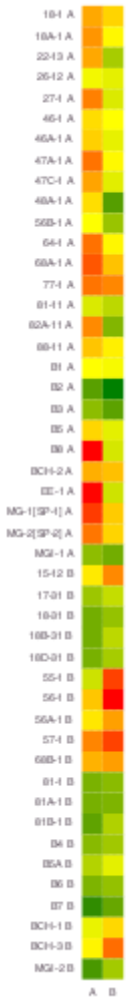

```
27×2 Array{Any,2}:
 "B8"           1.0
 "EE-1"         0.998613
 "MG-1(SP-1)"   0.956943
 "68A-1"        0.916159
 "64-1"         0.864026
 "47A-1"        0.859446
 "77-1"         0.857345
 "MG-2(SP-2)"   0.853707
 "27-1"         0.829554
 "82A-11"       0.807563
 "18A-1"        0.782265
 "47C-1"        0.745002
 "22-13"        0.734719
 ⋮
 "88-11"        0.659403
```

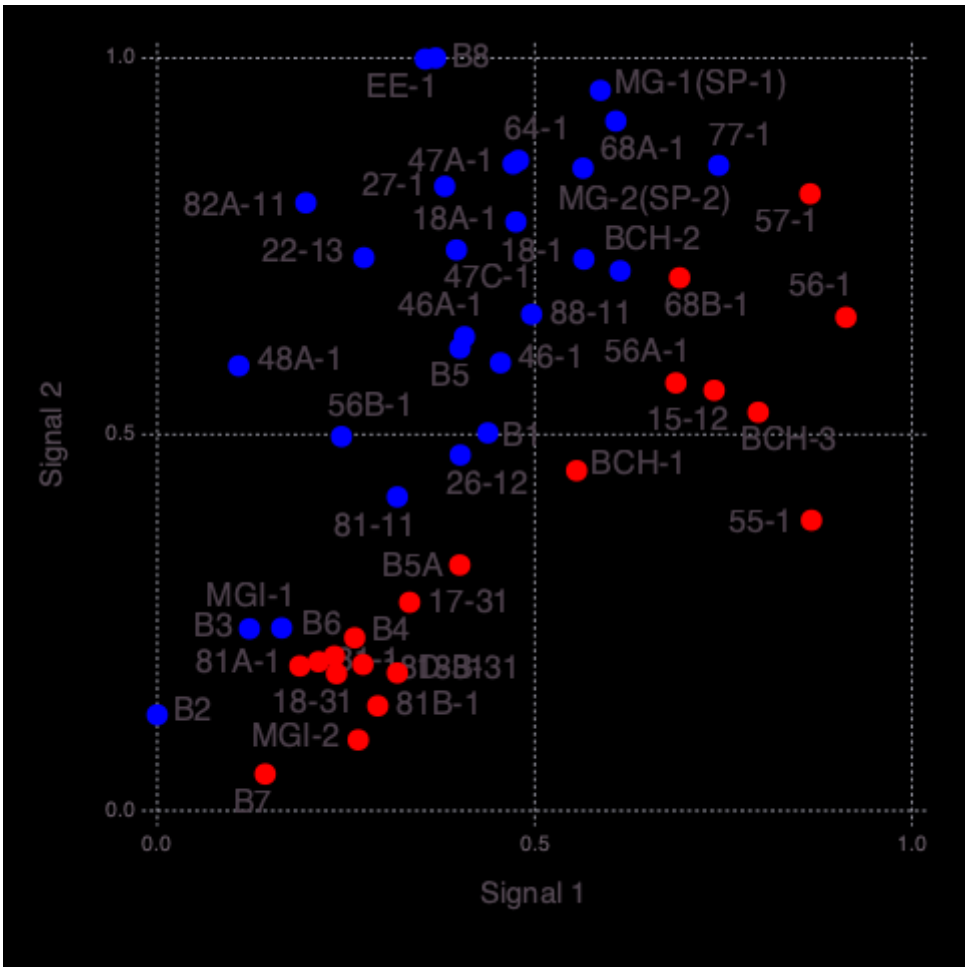
```
 "46A-1"       0.629757
 "B5"          0.614479
 "46-1"        0.594959
 "48A-1"       0.590979
 "B1"          0.501909
 "56B-1"       0.497064
 "26-12"       0.472464
 "81-11"       0.416937
 "MGI-1"       0.24275
 "B3"          0.241753
 "B2"          0.127328
```

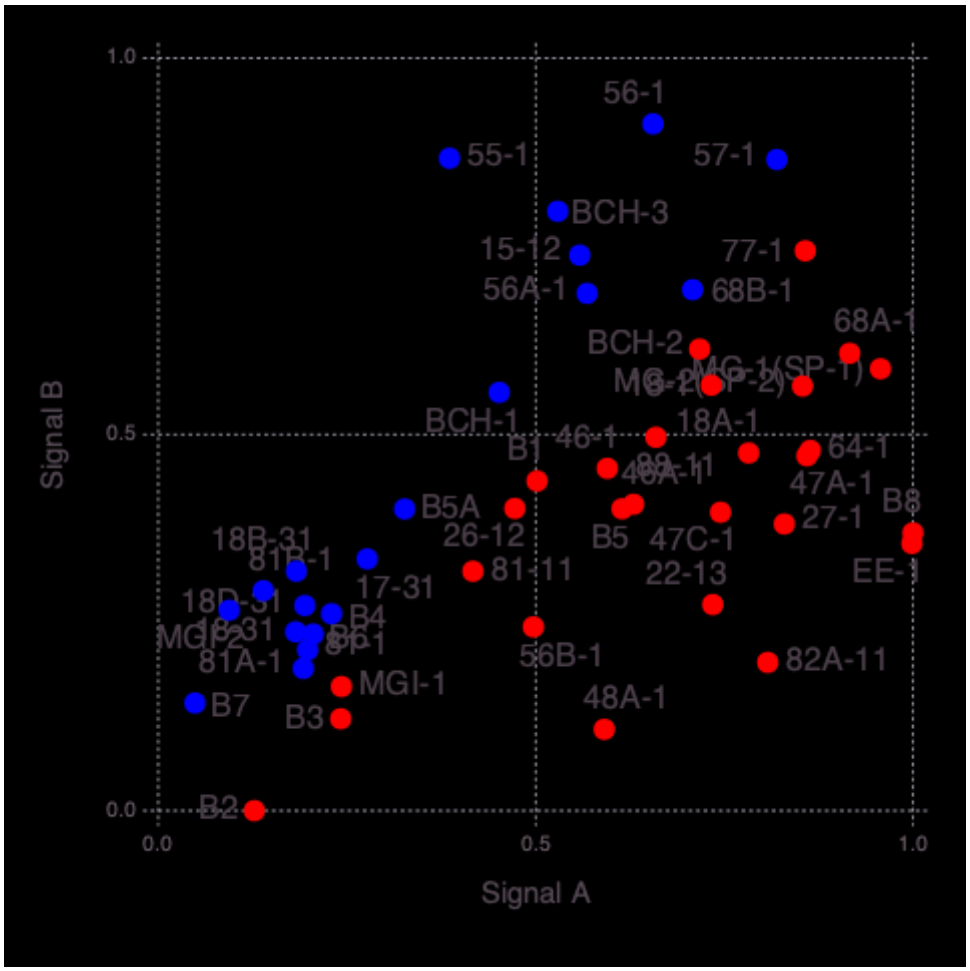
```
20×2 Array{Any,2}:
 "56-1"    1.0
 "55-1"    0.949937
 "57-1"    0.947965
 "BCH-3"   0.872622
 "15-12"   0.808709
 "68B-1"   0.758469
 "56A-1"   0.753147
 "BCH-1"   0.608981
 "B5A"     0.43926
 "17-31"   0.366493
 "18B-31"  0.348668
 "81B-1"   0.320223
 "18D-31"  0.298697
 "MGI-2"   0.291839
 "B4"      0.286734
 "18-31"   0.260379
 "B6"      0.257226
 "81-1"    0.234119
 "81A-1"   0.207054
 "B7"      0.156777
```

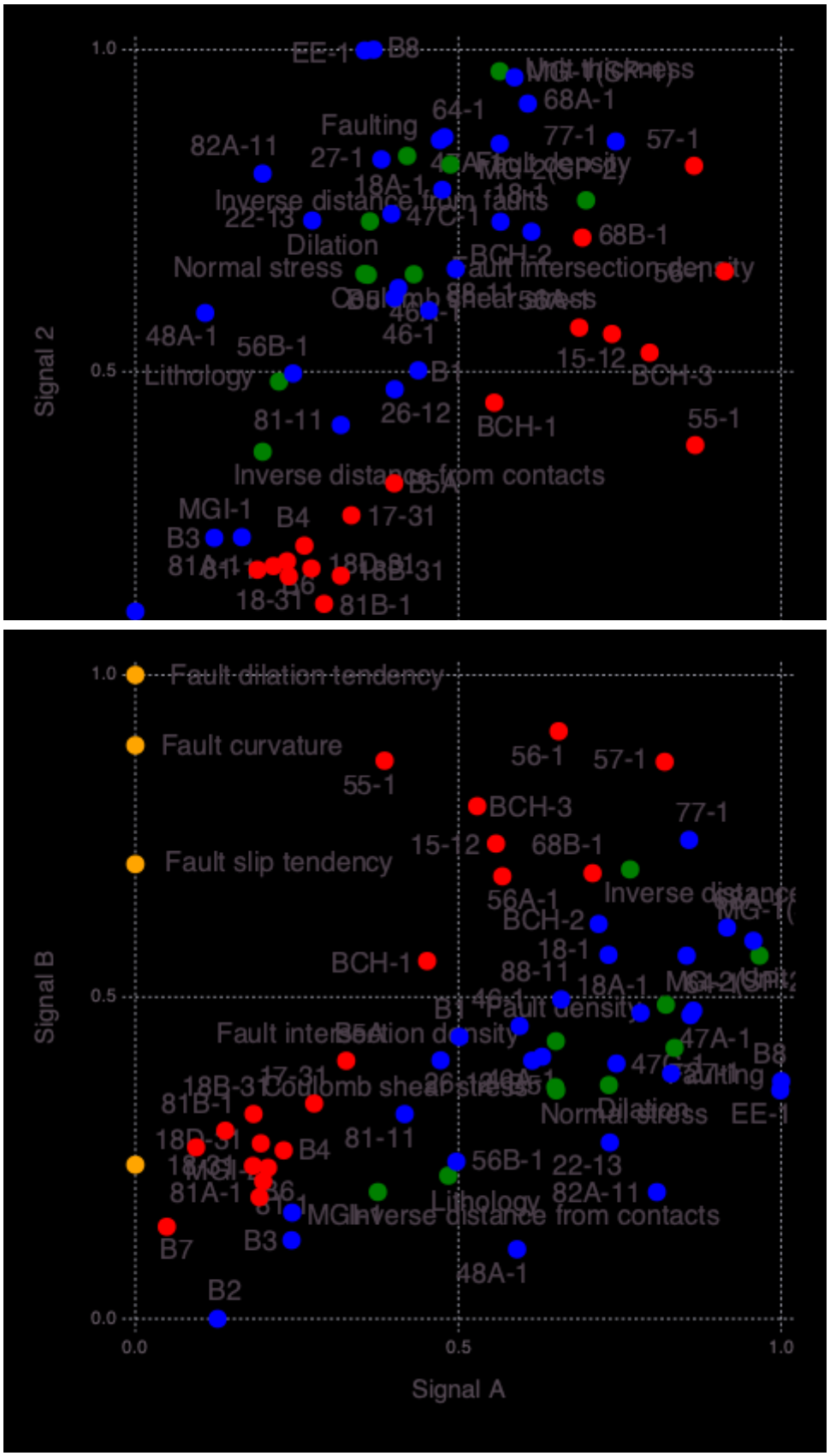



```
[ Info: Locations (signals=2)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:322
[ Info: Signal A (S2) Count: 27
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal B (S1) Count: 20
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal A -> A Count: 27
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal B -> B Count: 20
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal A (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
[ Info: Signal B (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
```




B8
EE-1
MG-1(SP-1)
64-1
68A-1
77-1
47A-1
27-1
MG-2(SP-2)
82A-11
18A-1
57-1
22-13
18-1
BCH-2
47C-1
56-1
46A-1
88-11
68B-1
48A-1
B5
46-1
56A-1
56B-1
15-12
BCH-3
B1
BCH-1
26-12
81-11
55-1
B5A
MGI-1
17-31
B3
B6
B4
81A-1
18-31
81B-1
B2
MGI-2
B7
1.0
0.5
0.0
0.0
0.5
1.0
Signal 2
Signal 1


1.0
0.5
0.0
0.0
0.5
1.0
Signal B
Signal A
56-1
55-1
57-1
BCH-3
15-12
77-1
56A-1
68B-1
68A-1
BCH-2
MG-1(SP-1)
BCH-1
18A-1
B1
46-1
64-1
47A-1
B8
B5A
27-1
18B-31
26-12
B5
47C-1
81B-1
81-11
22-13
EE-1
17-31
18D-31
B4
56B-1
82A-11
81A-1
MGI-1
48A-1
B7
B3
B2



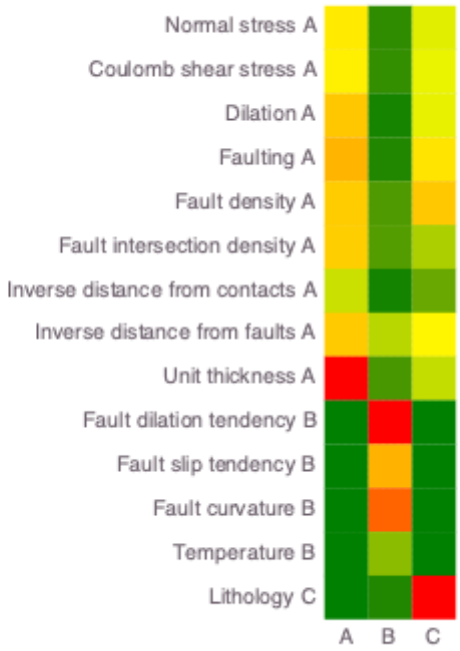

```
Signal importance (high->low): [3, 1, 2]
[ Info: Number of signals: 3
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:144
[ Info: Attributes (signals=3)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:148
┌ Warning: type Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.F
loat64,Core.Int64} not present in workspace; reconstructing
```

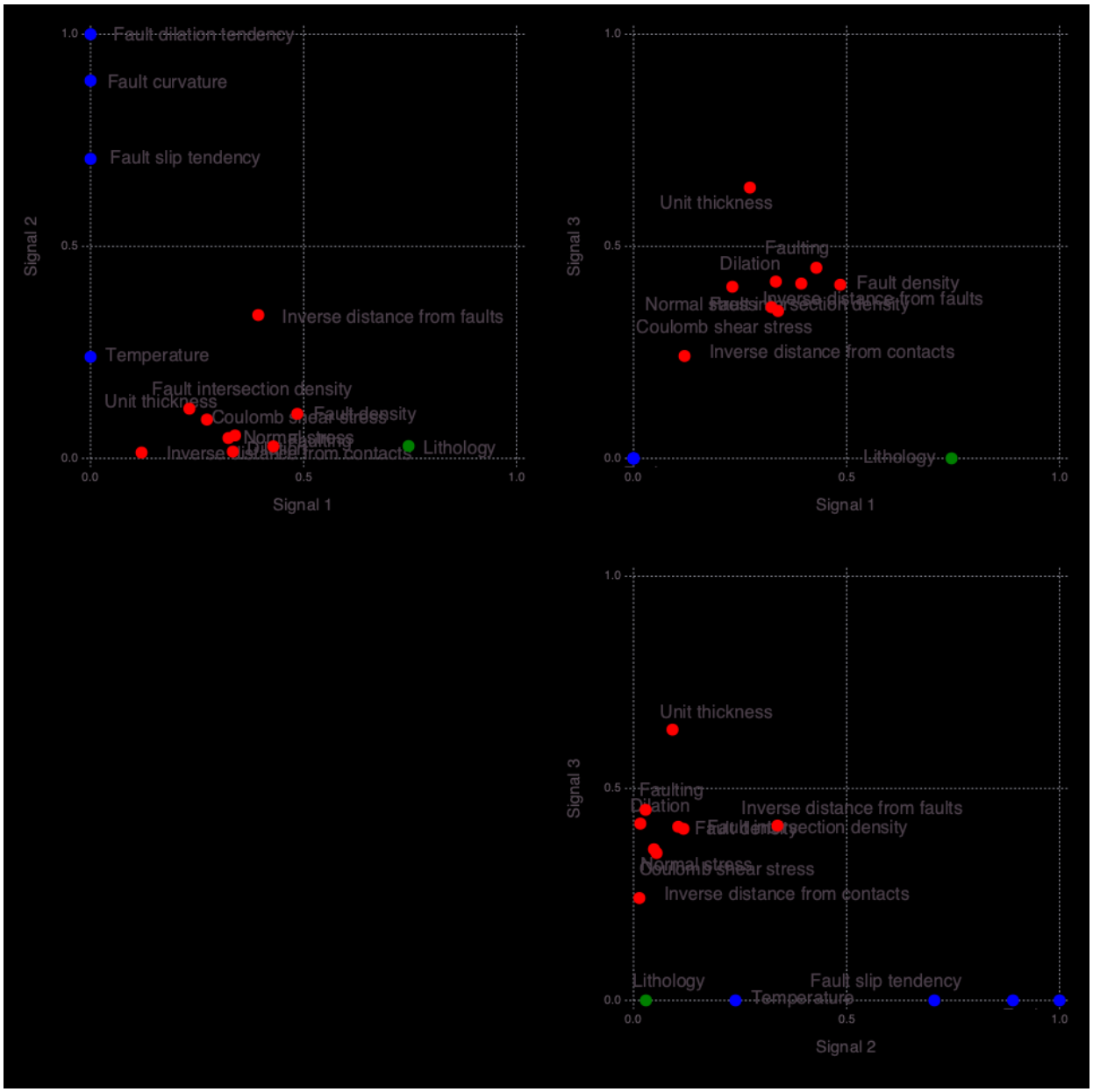
```
└ @ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
┌ Info: Robust k-means analysis results are loaded from file results-set0
0-v9-inv-750-1000-dlan/Hmatrix-3-3_14-1000.jld!
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Warning: type Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.F
loat64,Core.Int64} not present in workspace; reconstructing
└ @ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
┌ Info: Robust k-means analysis results are loaded from file results-set0
0-v9-inv-750-1000-dlan/Wmatrix-3-3_47-1000.jld!
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
```

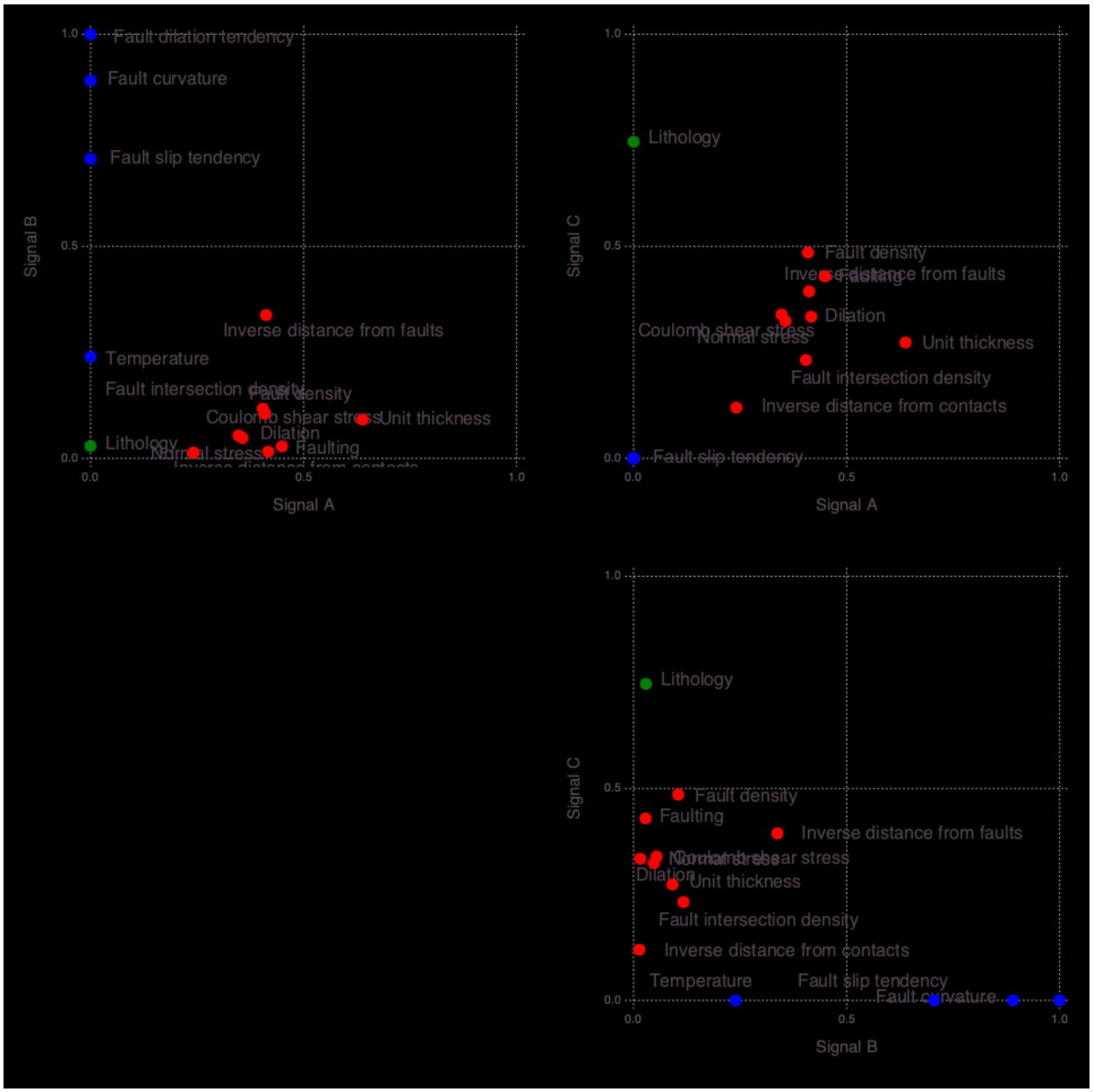
```
9×2 Array{Any,2}:
 "Unit thickness"                 1.0
 "Faulting"                       0.703863
 "Dilation"                       0.652914
 "Inverse distance from faults"   0.645557
 "Fault density"                  0.641279
 "Fault intersection density"     0.633706
 "Normal stress"                  0.558339
 "Coulomb shear stress"           0.544241
 "Inverse distance from contacts" 0.377979

4×2 Array{Any,2}:
 "Fault dilation tendency"  1.0
 "Fault curvature"          0.89069
 "Fault slip tendency"      0.706146
 "Temperature"              0.239306

1×2 Array{Any,2}:
 "Lithology"  1.0
```


```
┌ Warning: Procedure to find unique signals could not identify a solution
...
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
┌ Info: Signal A -> A Count: 9
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal B -> B Count: 4
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal C -> C Count: 1
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
┌ Info: Signal A (S3) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
┌ Info: Signal B (S2) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
┌ Info: Signal C (S1) (k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
```

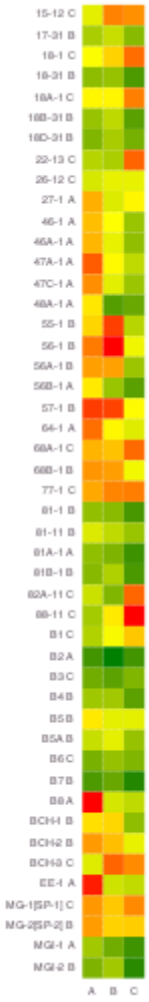

Normal stress A


Normal stress A
Coulomb shear stress A
Dilation A
Faulting A
Fault density A
Fault intersection density A
Inverse distance from contacts A
Inverse distance from faults A
Unit thickness A
Fault dilation tendency B
Fault slip tendency B
Fault curvature B
Temperature B
Lithology C
A
B
C


Fault dilation tendency
Fault curvature
Fault slip tendency
Inverse distance from faults
Temperature
Fault intersection density
Unit thickness
Coulomb shear stress
Fault density
Normal stress
Faulting
Dilation
Inverse distance from contacts
Lithology
Signal 1
Signal 2
Signal 3
1.0
0.5
0.0

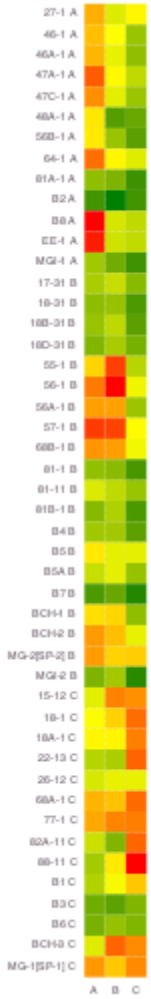

Fault dilation tendency
Fault curvature
Fault slip tendency
Inverse distance from faults
Temperature
Fault intersection density
Fault density
Coulomb shear stress
Unit thickness
Dilation
Lithology
Faulting
Signal B
Signal A
Lithology
Fault density
Inverse distance from faults
Faulting
Dilation
Coulomb shear stress
Normal stress
Unit thickness
Fault intersection density
Inverse distance from contacts
Fault slip tendency
Signal C
Signal A
Lithology
Fault density
Faulting
Inverse distance from faults
Coulomb shear stress
Normal stress
Dilation
Unit thickness
Fault intersection density
Inverse distance from contacts
Temperature
Fault slip tendency
Fault curvature
Signal C
Signal B

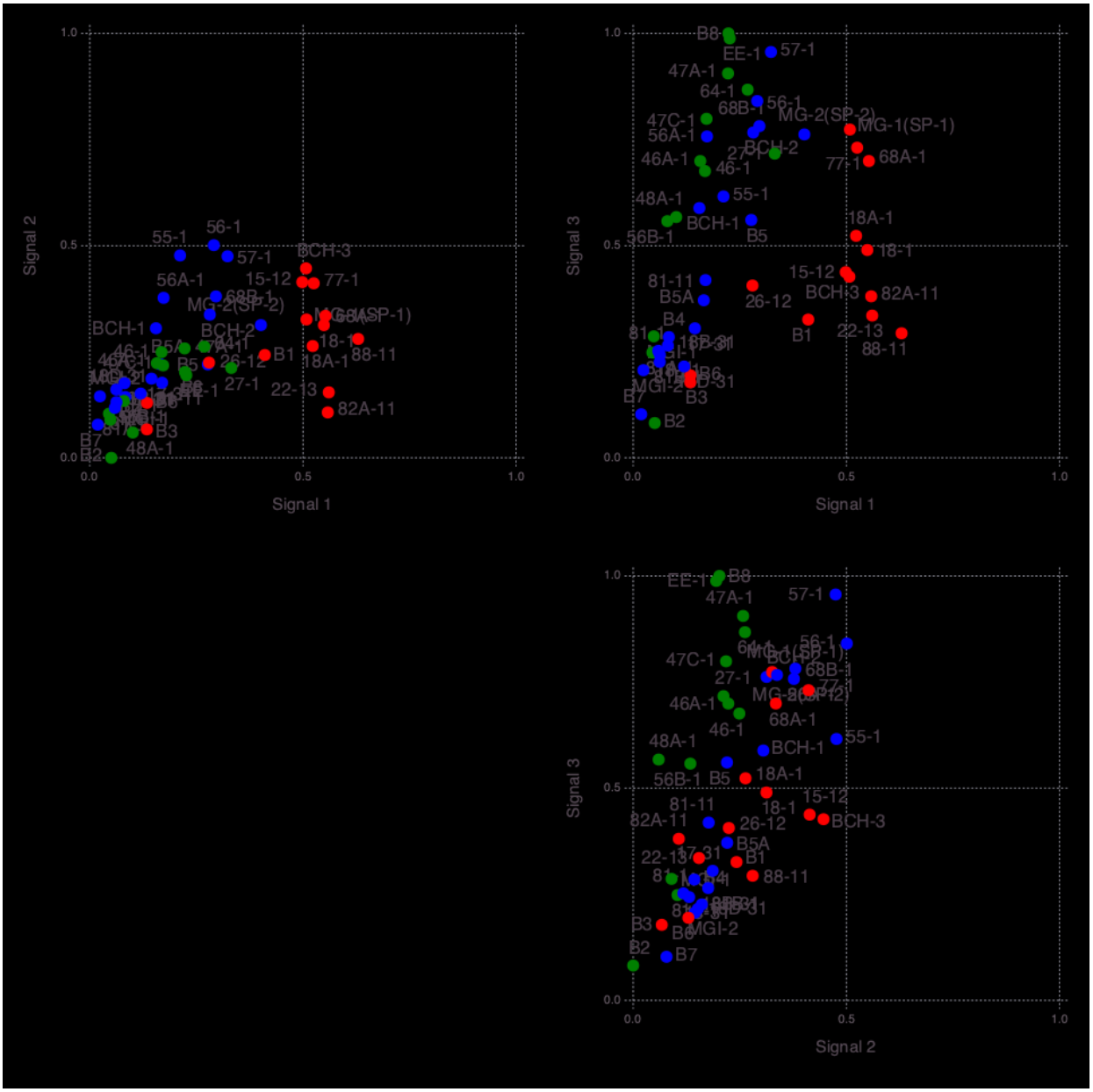
```
13×2 Array{Any,2}:
 "B8"     1.0
 "EE-1"   0.988215
 "47A-1"  0.905634
 "64-1"   0.867431
 "47C-1"  0.79874
 "27-1"   0.716696
 "46A-1"  0.699196
 "46-1"   0.675645
 "48A-1"  0.56726
 "56B-1"  0.557649
 "MGI-1"  0.286221
 "81A-1"  0.24804
 "B2"     0.0820308

20×2 Array{Any,2}:
 "56-1"        1.0
 "55-1"        0.951665
 "57-1"        0.947671
 "68B-1"       0.759123
 "56A-1"       0.752345
 "BCH-2"       0.67324
 "MG-2(SP-2)"  0.624464
 "BCH-1"       0.609265
 "B5A"         0.440143
 "B5"          0.439178
 "17-31"       0.372325
 "81-11"       0.353316
 "18B-31"      0.351038
 "81B-1"       0.32106
 "18D-31"      0.302397
 "MGI-2"       0.289056
 "B4"          0.286007
 "18-31"       0.261958
 "81-1"        0.234893
 "B7"          0.155895

14×2 Array{Any,2}:
 "88-11"       1.0
 "22-13"       0.890617
 "82A-11"      0.886939
 "68A-1"       0.878252
 "18-1"        0.872381
 "77-1"        0.834481
 "18A-1"       0.830688
 "MG-1(SP-1)"  0.807444
 "BCH-3"       0.805676
 "15-12"       0.791843
 "B1"          0.65222
 "26-12"       0.444381
 "B6"          0.213355
 "B3"          0.212844
```

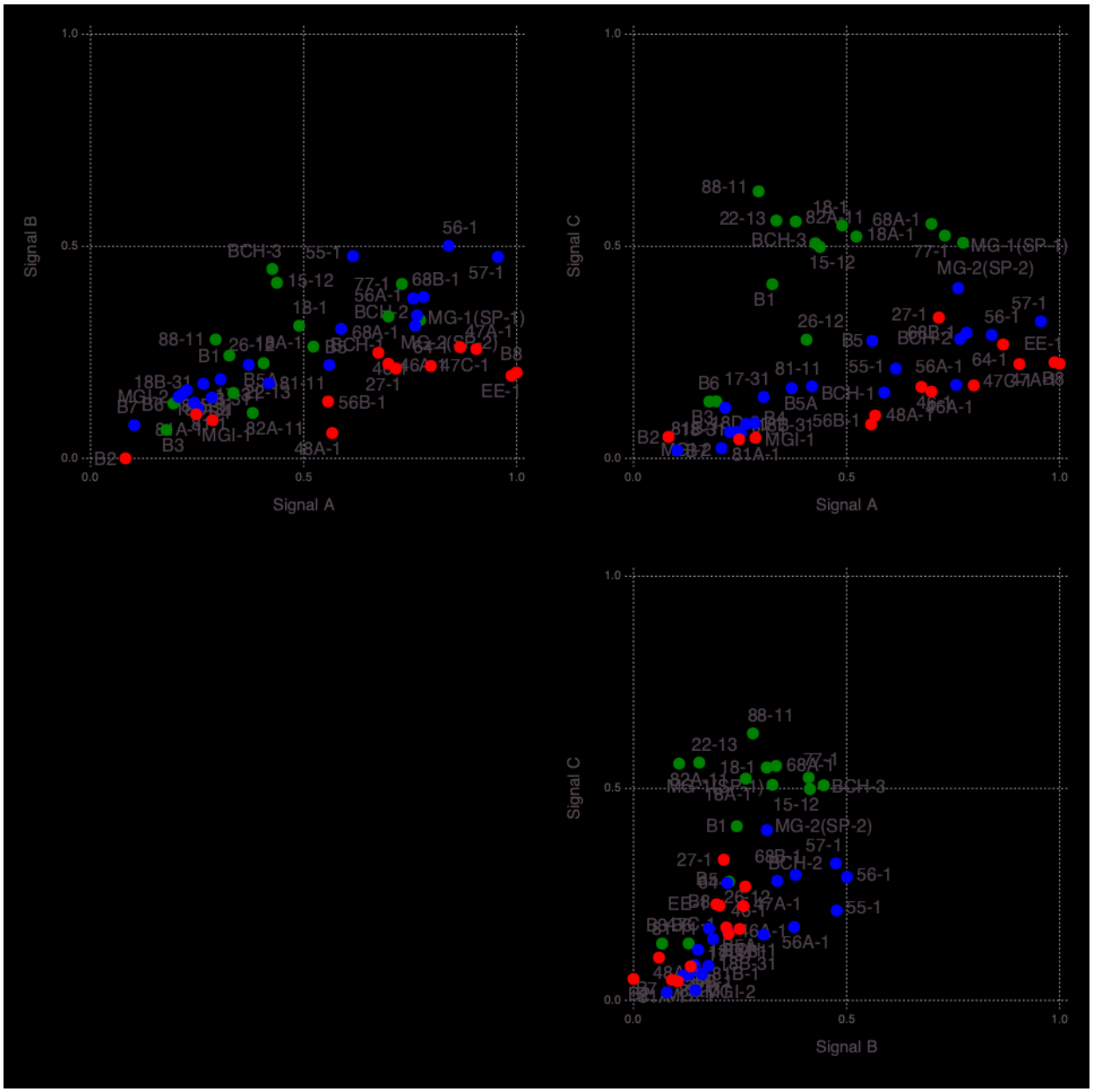


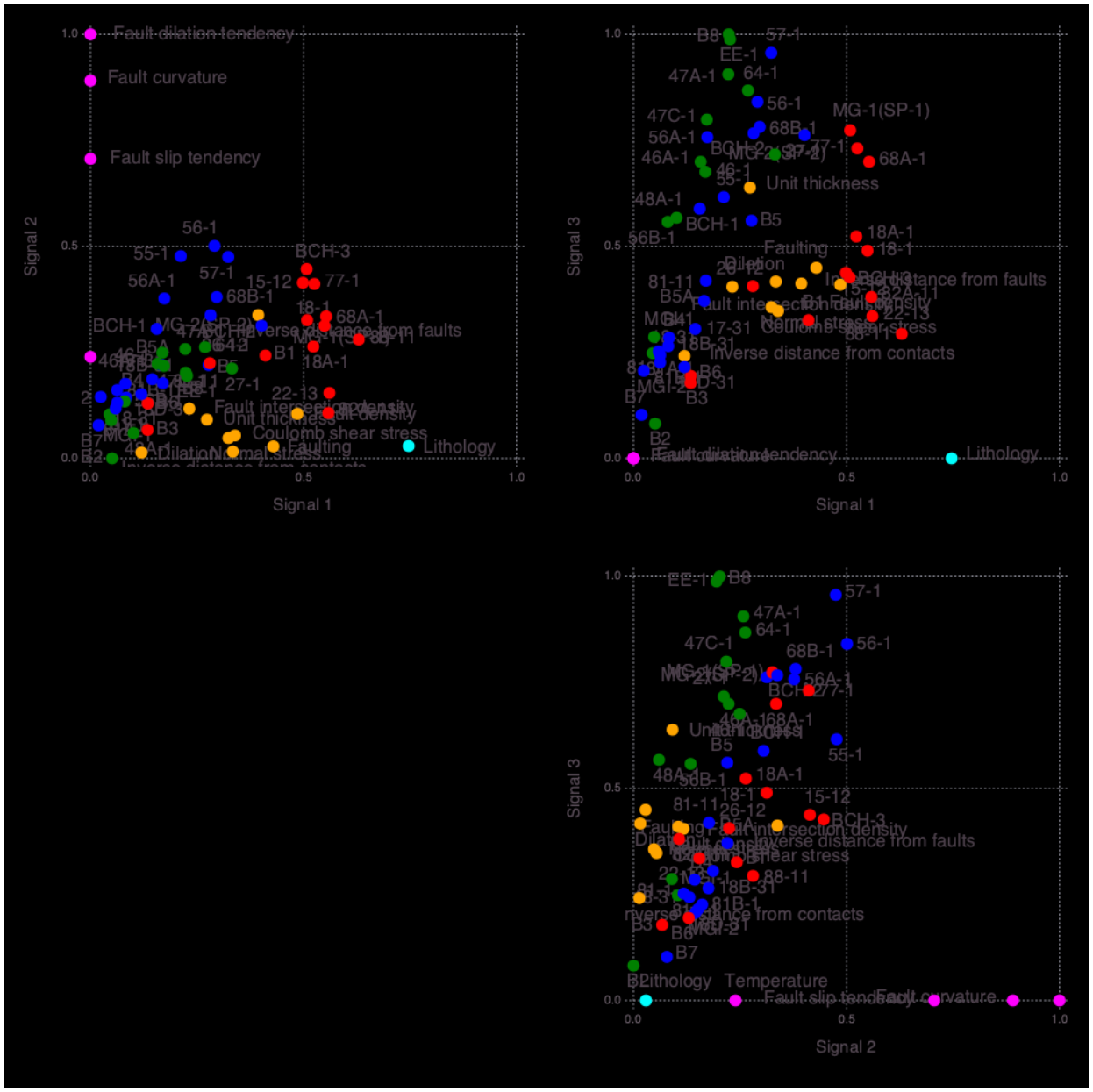

```
[ Info: Locations (signals=3)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:322
[ Info: Signal A (S2) Count: 20
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal B (S1) Count: 14
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal C (S3) Count: 13
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
[ Info: Signal C -> A Count: 13
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal A -> B Count: 20
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal B -> C Count: 14
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
[ Info: Signal A (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
```

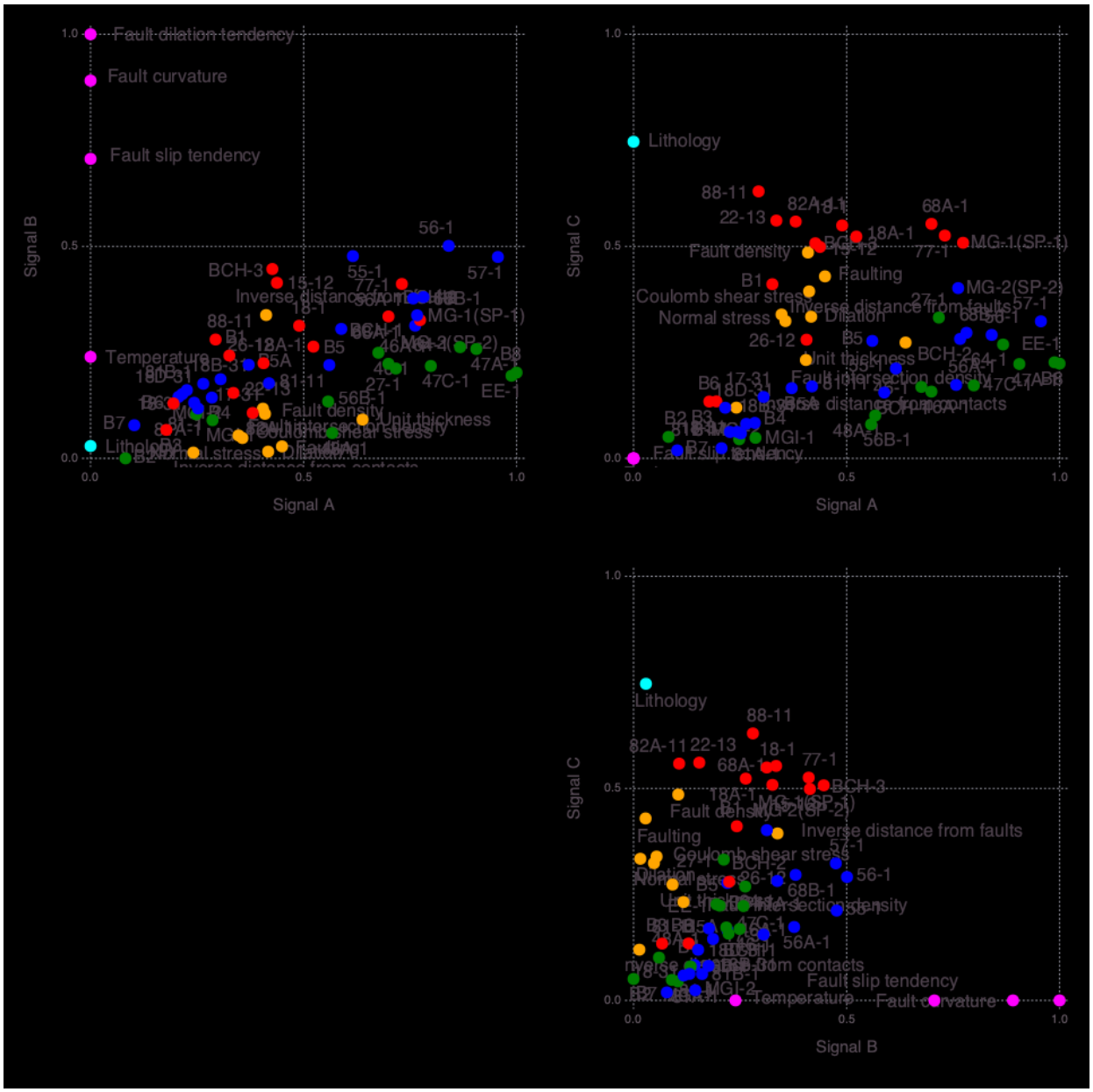
```
[ Info: Signal B (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
[ Info: Signal C (remapped k-means clustering)
└ @ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
```




Signal 1
Signal 2
Signal 3
0.0
0.5
1.0
55-1
56-1
57-1
BCH-3
15-12
77-1
56A-1
MG-2(SP-2)
MG-1(SP-1)
BCH-1
BCH-2
18-1
B1
18A-1
88-11
26-12
27-1
22-13
82A-11
B3
48A-1
B8
EE-1
47A-1
64-1
68B-1
47C-1
46-1
68A-1
B5
56B-1
81-11
B5A
B4
B6
MGI-2
B7
B2


Signal B
Signal A
Signal C
Signal A
Signal C
Signal B
0.0
0.5
1.0


Fault dilation tendency
Fault curvature
Fault slip tendency
Signal 2
Signal 1
Signal 3
Lithology
Unit thickness
Coulomb shear stress
Faulting
Fault intersection density
Inverse distance from faults
Inverse distance from contacts
Temperature
Fault slip tendency
Fault curvature


Fault dilation tendency
Fault curvature
Fault slip tendency
Temperature
Lithology
Signal A
Signal B
Signal C
Fault density
Faulting
Unit thickness
Inverse distance from faults
Coulomb shear stress
Normal stress
Dilation
Fault intersection density
Inverse distance from contacts
MG-1(SP-1)
MG-2(SP-2)
MGI-1
BCH-3
BCH-2
56-1
57-1
55-1
77-1
68A-1
68B-1
88-11
82A-11
22-13
18-1
18A-1
56A-1
56B-1
47C-1
47A-1
EE-1
27-1
26-12
B1
B5
B5A
B7
B8

Out[69]:
```
([[2, 1], [3, 2, 1]], [['B', 'B', 'A', 'B', 'A', 'B', 'B', 'A', 'A', 'A'
…  'B', 'A', 'B', 'A', 'B', 'A', 'A', 'A', 'A', 'B'], ['C', 'B', 'C',
'B', 'C', 'B', 'B', 'C', 'C', 'A'  …  'B', 'A', 'B', 'B', 'C', 'A', 'C',
'B', 'A', 'B']], [['A', 'A', 'A', 'A', 'B', 'B', 'B', 'B', 'A', 'A', 'A',
'A', 'A', 'A'], ['A', 'A', 'A', 'A', 'B', 'B', 'B', 'B', 'A', 'A', 'A',
'A', 'A', 'C']])
```