Geysir

Analysis of pitch class predominance and amplitude of Geysir, Haukadalur valley, Iceland

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INTRODUCTION

The sounds of geological phenomena are generally noise. Wind, glaciers, oceans, streams, and other geological sounds present a vast content of frequencies that often obscures individual pitches or groups of pitches. However, noise varies from sound to sound with different pitch predominance and patterns. This variance contributes to the signature that makes several noise sounds unique. In this study, the sound[1] of one the geysers in the Geysir system of the Haukadalur valley, 180 miles Northeast of Reykjavik, Iceland, is recorded and analyzed in multiple time segments, each with its own pitch predominance and, therefore, signature. The analysis is further adapted into a piece for seven spatialized pianists and electronics of my authorship, *Geysir*[2], which features the amplitude and predominant pitch class fluctuations throughout the geyser sample.

This study presents analyzes 11 minutes of recording using a suite of software for the identification of amplitude and frequency (pitch) content. The pitches presented in this analysis are quantized –simplified– to equal temperament (C, C#, D, D#, etc.) for in order to be adapted to the piano's tuning affordances.

METHODS

1. The recording was made with two omnidirectional microphones with a frequency response peaking at 3.5 dB at 10.3 kHz.

2. Using SPEAR software, the audio recording was re-synthesized in order to manipulate, organize, and calculate the predominance of the frequency content (Fig. 1). Once re-synthesized, the audio was segmented in seven regions, from high to low, equivalent to a piano's seven complete octaves, from the lowest (C1) to the highest (C7).

Each of these regions became an independent file (Fig. 2). The partials with the amplitudes under -45 dB (the quietest) were eliminated, remaining only the loudest ones (Fig. 3).

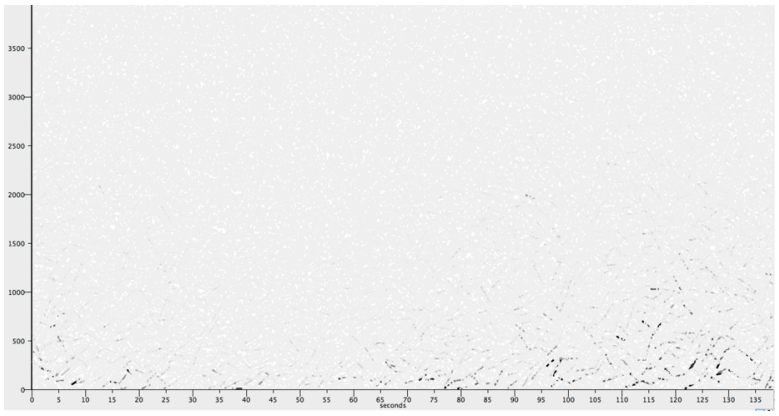

Fig. 1. Entirety of re-synthesized partials (frequencies) of the first 2'15'' of the geyser recording

[1] http://www.christopherlunamega.com/works/field-recordings/geysir
[2] http://www.christopherlunamega.com/works/compositions/geysir-composition

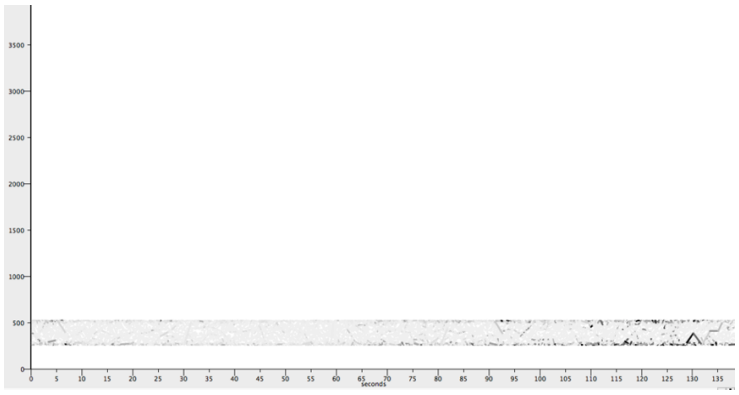

Fig. 2. Segmented region (262-523 Hz)

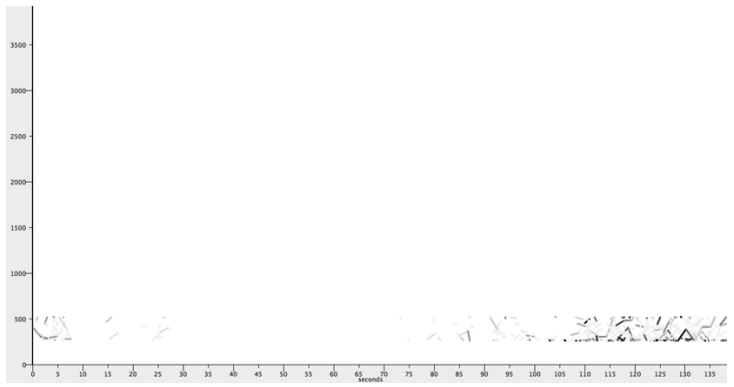

Fig. 3. Segmented region after elimination of partials -25 dB

3. Conversion of the file format generated in SPEAR –Sound Description Interchange Format (.sdif) into a text file (.txt) was done with the Orchidée computer aided orchestration software.

4. Using Max MSP's Bach object library, the re-synthesized audio data encoded in the (.txt) file was converted into music notation. A tool was generated for quantizing the complex rhythms and micro-tonal tunings of the geyser into simple rhythms adequate for pulse/time reference and the chromatic equal-tempered tuning system.[3] The quantized audio data was translated into Music Exchangeable Markup Language format (.xml), which makes the contents compatible with data applications and music engraving software such as Sibelius or Finale.

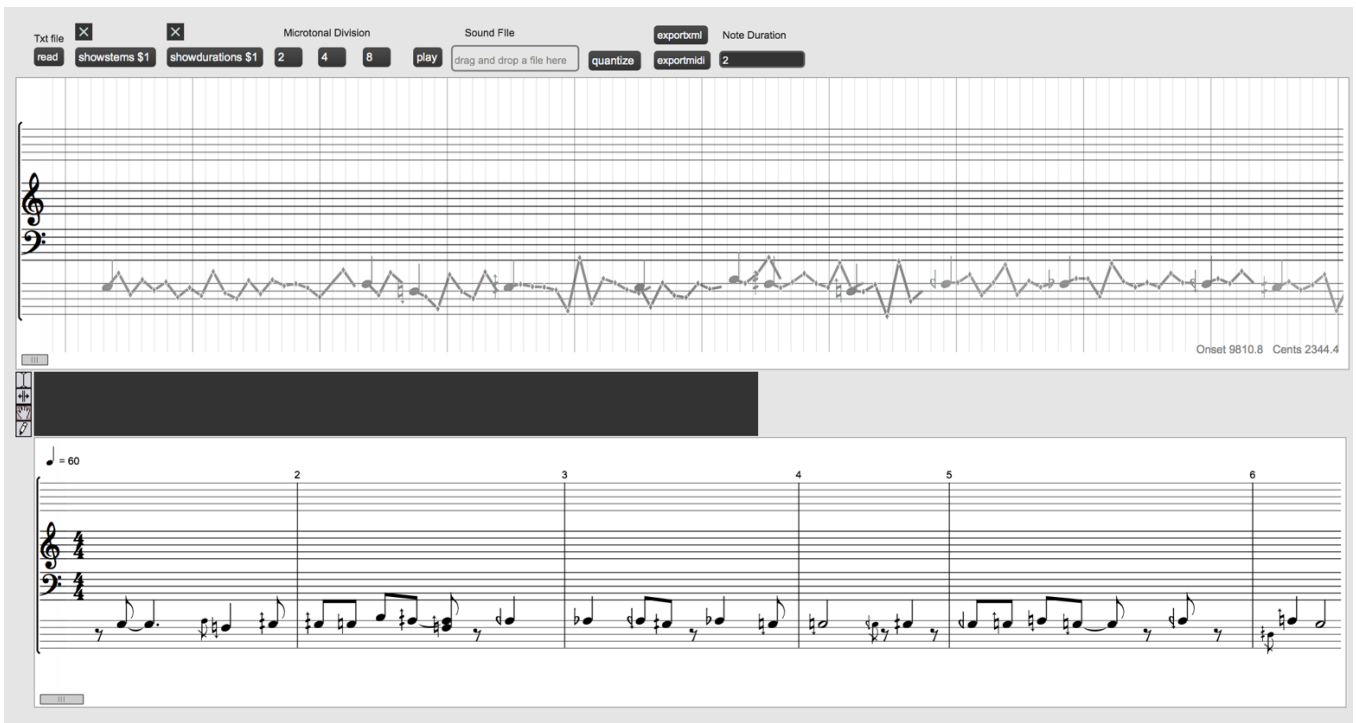

Fig. 4. Max MSP patch, including the bach.roll, bach.score, quantization, and .xml conversion tools[4]

5. The last phase of the analysis is the classification of the geyser's pitch classes derived from the previous processes. Using the BaseX database engine, all the pitches contained in the .xml file were organized by predominance/octave under the criteria of onset count and duration. The program groups the pitch classes and adds the total time of their total onsets within a specific time segment (i.e., 16 onsets with a total of 20 seconds within a 25 second segment). Lastly, a list in descending order from most prominent to least prominent is generated for time intervals varying between 12 and 24 seconds. The lists derived from this analysis were adapted entirely into the musical score for *Geysir*, for seven spatialized pianists and electronics.

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[3] Equal-tempered tunings were chosen due to the fact that the music resulting from this analysis would be written for seven pianos. Quantization choices will vary depending on the affordances of the instruments that will perform. String instruments and some wind instruments can perform micro-tonal divisions up to $^1/_8$ of a tone, as opposed to the piano, tuned to equal ½ of a tone.

[4] Max MSP programming designed by Maxwell Tfirn.

PITCH-CLASS PREDOMINANCE ANALYSIS RESULTS

The information provided in this section is a description of each of the elements of the following figure.

```
<group staff="1" measures="1,2,3,4">
  <pitch value="C#" duration="1920" count="15" rank3="high ●" rank4="high ●"/>
  <pitch value="C" duration="1408" count="11" rank3="high ●" rank4="medium ◇"/>
  <pitch value="Eb" duration="1280" count="10" rank3="medium ◇" rank4="medium ◇"/>
  <pitch value="D" duration="1280" count="10" rank3="medium ◇" rank4="medium ◇"/>
  <pitch value="F" duration="896" count="7" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="E" duration="256" count="2" rank3="low ╳" rank4="ruled out ⌀"/>
```

Fig. 5. First 20 seconds of the pitch predominance analysis, Staff 1 (highest octave of the piano).[5]
The full analysis is available at https://chlunamega.github.io/public/field-recordings/geysir/geysir-pitch-clas´s-predominance-analysis.pdf

Octave segmentation

Staff 1: C7 (piano 7)	2093-4186 Hz
Staff 2: C6 (piano 6)	1047-2093 Hz
Staff 3: C5 (piano 5)	523-1047 Hz
Staff 4: C4 (piano 4)	262-523 Hz
Staff 5: C3 (piano 3)	131-262 Hz
Staff 6: C2 (piano 2)	65-131 Hz
Staff 7: C1 (piano 1)	33-65 Hz

Pitch categories by predominance

The data in this document displays the pitches with highest predominance in each octave, from highest to lowest, within the noise of the geyser. These pitches are labeled in either of three predominance categories: high (●), medium (◇), low (╳), and/or ruled out (⌀). These encodings are kept for the performers in the musical score.

Time

Time is presented in measures. Each measure is 4 seconds long. In the first segment of the analysis –<group staff="1" measures="1,2,3,4">, if each measure is 4" long, the total time of measures 1, 2, 3, and 4 is 16" (4 measures x 4". To Identify a specific time location of any of the measures, multiply it by 4 and then subtract 4. For example, for <group staff="1" measures="30,31,32,33,34">, the time location of measure 30 is second 116, or time cue 01'56".

Syntax

<Group staff	octave analyzed (highest octave is group staff "1"; lowest octave is group staff "7")
Measures>	specifies the total amount of measures in the segment analyzed.

<Pitch value	the pitch equivalence of the partial's frequency (2218 HZ=C#7)
Duration	total duration of the partial's occurrences in the segment. Value displayed in milliseconds (1920 milliseconds=1.9 seconds)
Count	number of iterations of the given pitch or frequency in the segment
Rank	predominance criteria (low, medium, high). Rank 3 includes more pitches than Rank 4, which rules out low counts/durations
Density>	when there is no information for given measures of a group staff, the amplitude (intensity) of the geyser was so low that there was no statistically significant pitch.

PITCH-CLASS PREDOMINANCE ANALYSIS NOTATION DISPLAY

The examples in this section feature the music notation and sound characteristics of selected segments of each segmented octave of the geyser recording, from the highest (staff 1) to the lowest (staff 7).

The main elements from the pitch-class predominance analysis that are represented in music notation are:

1) The register, according to the octave categories shown above (Staff=1–C7 to Staff=7–C1)
2) The note-heads, which maintain the symbols used in the pitch-class predominance analysis.

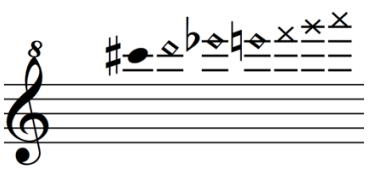
[5] BaseX programming by Jon Gomez.

The sound examples present the pitch collections in the following order:

1) as the displayed pitch collection in ascending order (as a scale), mapping loudness to predominance
2) as a cluster with all the notes sounding simultaneously at equal intensities
3) as a succession of chords featuring high predominance, medium predominance and low predominance pitches in succession
4) as a fragment of the actual performed part in the score

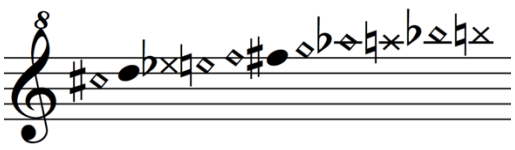
“Staff=1” | 2093-4186 Hz | 02:32 in recording and composition

```
<group staff="1" measures="38,39,40,41">
  <pitch value="C#" duration="8192" count="64" rank3="high ●" rank4="high ●"/>
  <pitch value="Eb" duration="4608" count="36" rank3="medium ◇" rank4="medium ◇"/>
  <pitch value="D" duration="3968" count="31" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="C" duration="3712" count="29" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="E" duration="2304" count="18" rank3="low ╳" rank4="low ╳"/>
  <pitch value="F" duration="896" count="7" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="F#" duration="896" count="7" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="Ab" duration="384" count="3" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="A" duration="128" count="1" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="G" duration="128" count="1" rank3="low ╳" rank4="ruled out ø"/>
```



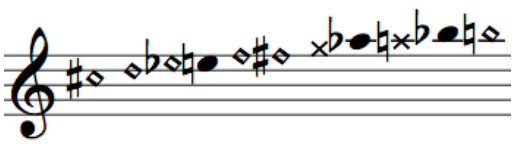
“Staff=2” | 1047-2093 Hz | 03:44 in recording and composition

```
<group staff="2" measures="57,58,59,60,61,62">
  <pitch value="D" duration="21632" count="169" rank3="high ●" rank4="high ●"/>
  <pitch value="F#" duration="19072" count="149" rank3="high ●" rank4="high ●"/>
  <pitch value="E" duration="13696" count="107" rank3="medium ◇" rank4="medium ◇"/>
  <pitch value="C#" duration="11776" count="92" rank3="medium ◇" rank4="medium ◇"/>
  <pitch value="F" duration="11776" count="92" rank3="medium ◇" rank4="medium ◇"/>
  <pitch value="G" duration="11136" count="87" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="Bb" duration="9856" count="77" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="Eb" duration="9472" count="74" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="Ab" duration="8960" count="70" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="A" duration="8320" count="65" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="B" duration="5504" count="43" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="C" duration="896" count="7" rank3="low ╳" rank4="ruled out ø"/>
```



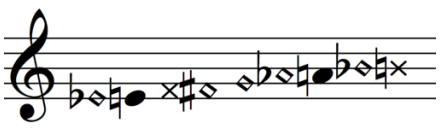
“Staff=3” | 523-1047 Hz | 01:32 in recording and composition

```
<group staff="3" measures="23,24,25">
  <pitch value="Bb" duration="10240" count="80" rank3="high ●" rank4="high ●"/>
  <pitch value="E" duration="7936" count="62" rank3="high ●" rank4="high ●"/>
  <pitch value="Ab" duration="7168" count="56" rank3="high ●" rank4="medium ◇"/>
  <pitch value="B" duration="5632" count="44" rank3="medium ◇" rank4="medium ◇"/>
  <pitch value="F#" duration="5248" count="41" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="F" duration="4736" count="37" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="Eb" duration="4096" count="32" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="D" duration="3968" count="31" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="A" duration="3840" count="30" rank3="low ╳" rank4="low ╳"/>
  <pitch value="G" duration="3072" count="24" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="C#" duration="1920" count="15" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="C" duration="768" count="6" rank3="low ╳" rank4="ruled out ø"/>
```



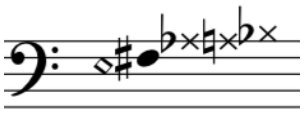
“Staff=4” | 262-523 Hz | 05:28 in recording and composition

```
<group staff="4" measures="82,83,84,85">
  <pitch value="Eb" duration="3584" count="28" rank3="high ●" rank4="high ●"/>
  <pitch value="A" duration="3712" count="28" rank3="high ●" rank4="high ●"/>
  <pitch value="E" duration="3584" count="27" rank3="high ●" rank4="high ●"/>
  <pitch value="F#" duration="3200" count="25" rank3="high ●" rank4="high ●"/>
  <pitch value="G" duration="2944" count="22" rank3="high ●" rank4="medium ◇"/>
  <pitch value="Bb" duration="2944" count="22" rank3="high ●" rank4="medium ◇"/>
  <pitch value="Ab" duration="2432" count="19" rank3="medium ◇" rank4="medium ◇"/>
  <pitch value="B" duration="2176" count="16" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="F" duration="1152" count="9" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="D" duration="896" count="7" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="C#" duration="1024" count="7" rank3="low ╳" rank4="ruled out ø"/>
```



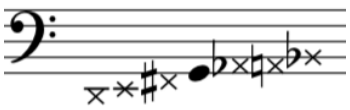
“Staff=5” | 131-262 Hz | 01:32 in recording and composition

```
<group staff="5" measures="21,22,23,24">
  <pitch value="F#" duration="8320" count="64" rank3="high ●" rank4="high ●"/>
  <pitch value="Ab" duration="2816" count="21" rank3="low ╳" rank4="low ╳"/>
  <pitch value="G" duration="2560" count="20" rank3="low ╳" rank4="low ╳"/>
  <pitch value="E" duration="2176" count="17" rank3="low ╳" rank4="low ╳"/>
  <pitch value="F" duration="1408" count="10" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="B" duration="1152" count="9" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="C" duration="896" count="7" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="Bb" duration="640" count="5" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="A" duration="384" count="3" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="D" duration="128" count="1" rank3="low ╳" rank4="ruled out ø"/>
  <pitch value="C#" duration="128" count="1" rank3="low ╳" rank4="ruled out ø"/>
```



“Staff=6” | 65-131 Hz | 05:40 in recording and composition

```
<group staff="6" measures="86,87,88,89">
  <pitch value="G" duration="6016" count="44" rank3="high ●" rank4="high ●"/>
  <pitch value="D" duration="768" count="6" rank3="low ╳" rank4="ruled out ⌀"/>
  <pitch value="F#" duration="768" count="5" rank3="low ╳" rank4="ruled out ⌀"/>
  <pitch value="Ab" duration="512" count="4" rank3="low ╳" rank4="ruled out ⌀"/>
  <pitch value="E" duration="384" count="3" rank3="low ╳" rank4="ruled out ⌀"/>
  <pitch value="F" duration="384" count="2" rank3="low ╳" rank4="ruled out ⌀"/>
  <pitch value="Bb" duration="256" count="2" rank3="low ╳" rank4="ruled out ⌀"/>
  <pitch value="A" duration="256" count="2" rank3="low ╳" rank4="ruled out ⌀"/>
  <pitch value="C" duration="128" count="1" rank3="low ╳" rank4="ruled out ⌀"/>
```



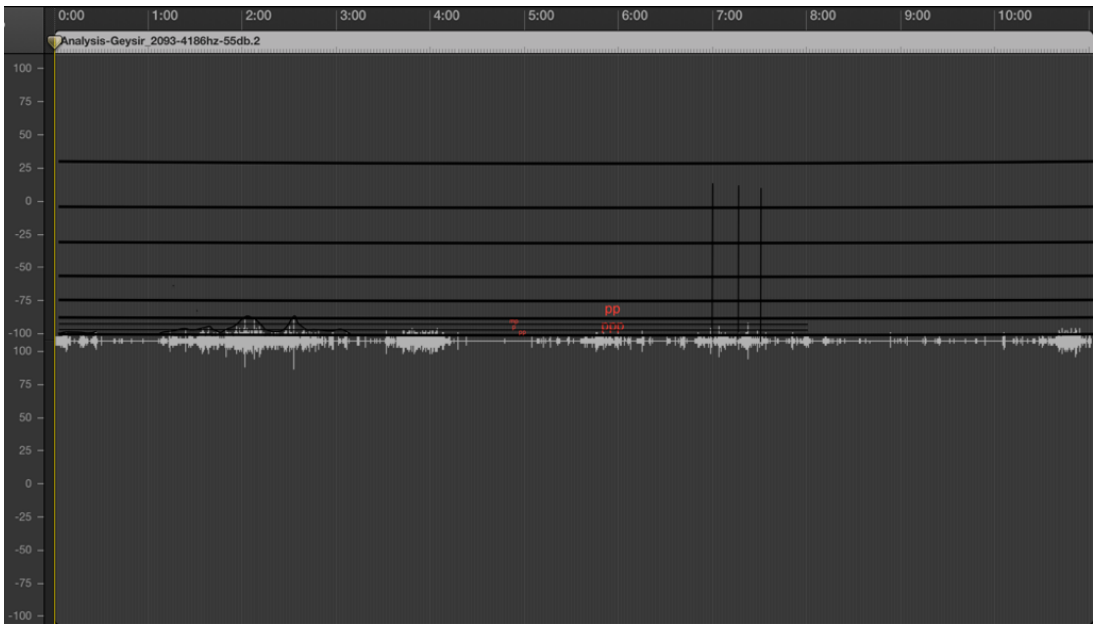
“Staff=7” | 33-65 Hz | 06:12 in recording and composition

```
<group staff="7" measures="92,93,94">
  <pitch value="G" duration="2560" count="7" rank3="high ●" rank4="high ●"/>
  <pitch value="F#" duration="640" count="4" rank3="medium ◇" rank4="low ╳"/>
  <pitch value="Bb" duration="256" count="2" rank3="low ╳" rank4="ruled out ⌀"/>
  <pitch value="A" duration="128" count="1" rank3="low ╳" rank4="ruled out ⌀"/>
```

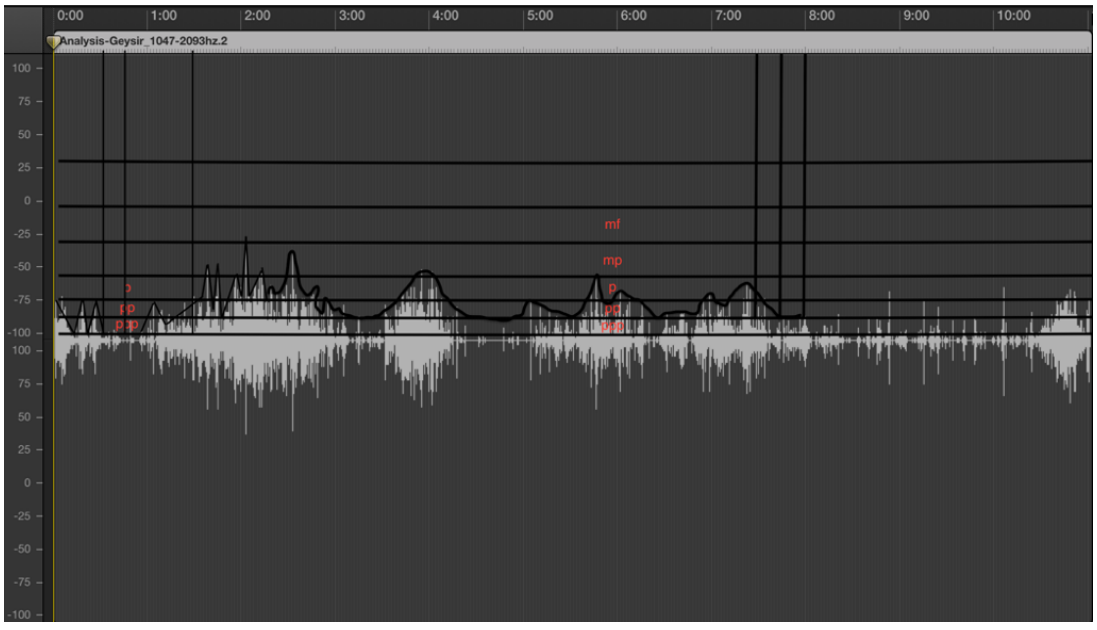
AMPLITUDE ANALYSIS

The seven re-synthesized frequency segments[6] processed in SPEAR were imported individually to Logic. Automatically, a waveform display is generated in which the y-axis represents amplitude in dB (decibels) and the x-axis represents time. A screenshot of each waveform display was segmented into seven dynamics regions: ***ppp***, ***pp***, ***p***, ***mp***, ***mf***, ***f***, ***ff***. A drawn contour, shown in various sections of the figures below, was used to track the dynamic evolution of the geyser's frequency regions through time. Each of the frequency regions' contours was transcribed to each of the 7 parts of the score.

The dynamic contours of the frequency regions with lowest amplitudes –staff 1 and staff 7, which present the highest and lowest frequencies– were occasionally altered for balance and intelligibility. For example, staff 1, in the figure below, presents a very brief spike at ***pp***, its highest amplitude in the entire 11 minutes of recording. For this reason, a sub-segmentation was made within the ***ppp*** range, where the highest peak of is re-interpreted as a ***mp***. In the comparative amplitude analyses below, note the geyser's loudest frequency regions, from 131 to 1047 Hz –staff 3 to staff 5.

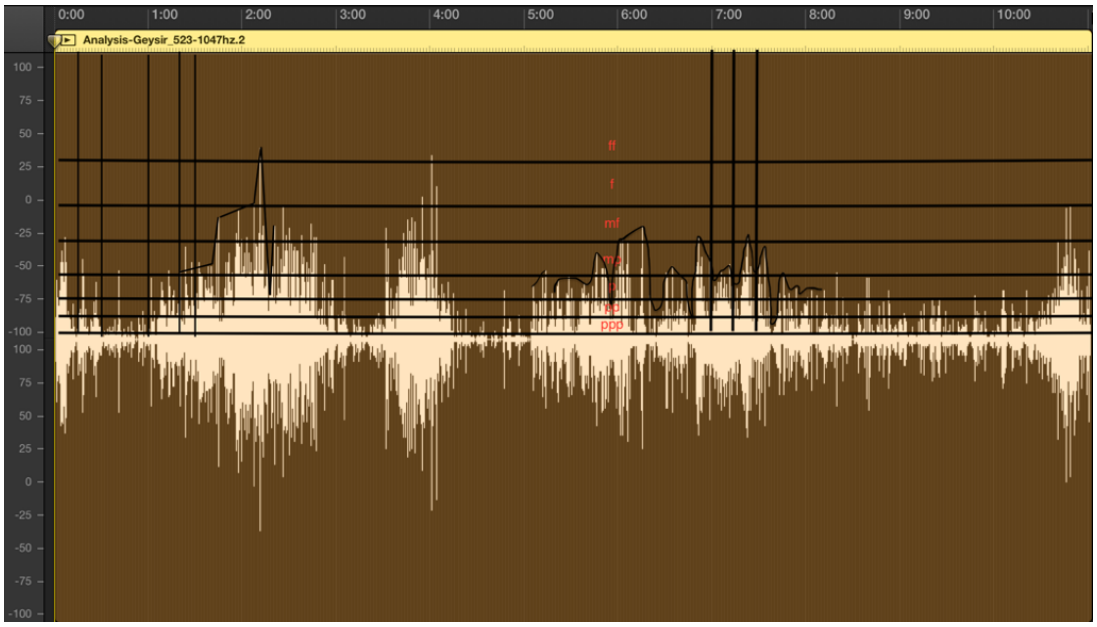


Staff=1 (C7–C8)

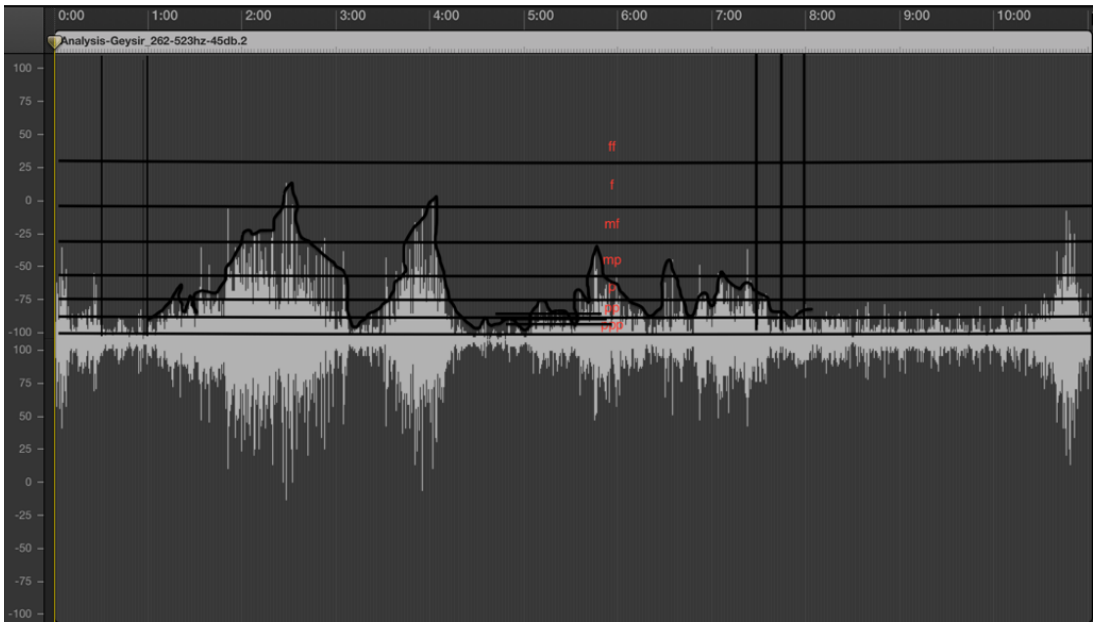


Staff=2 (C6–C7)

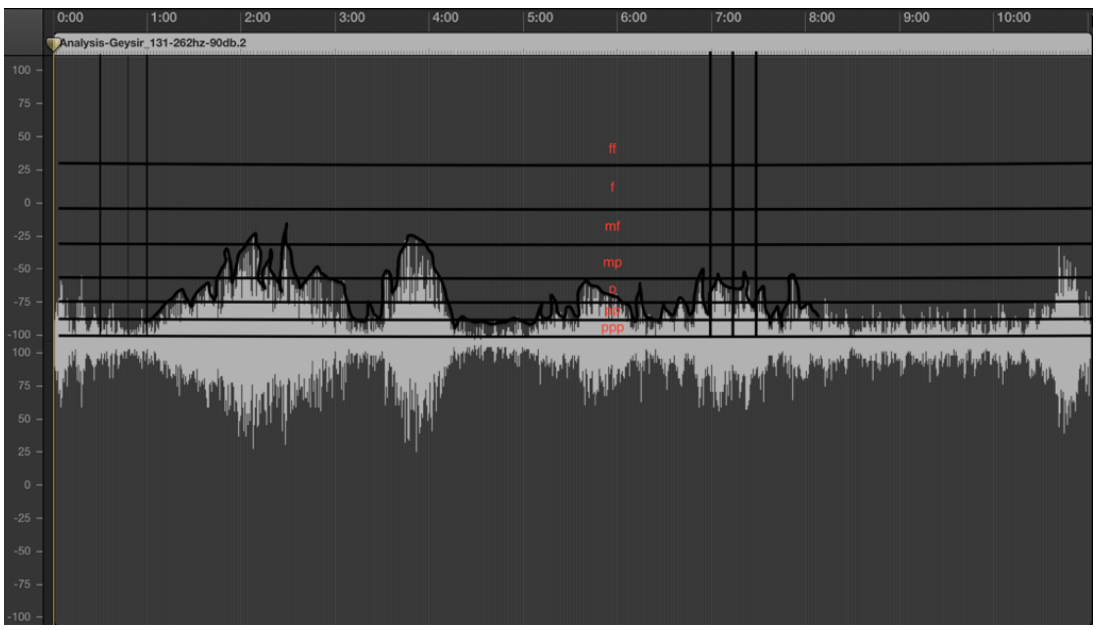
[6] Frequency segments are termed "staff=1, staff=2, etc." in the Pitch-Class Predominance Analysis)



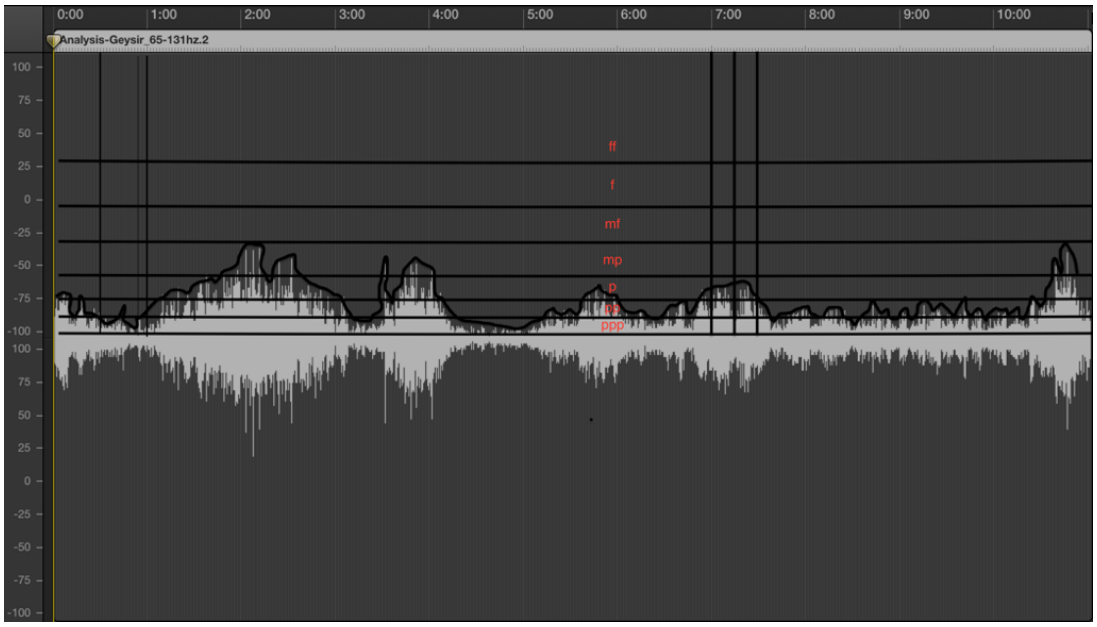
Staff=3 (C5–C6)



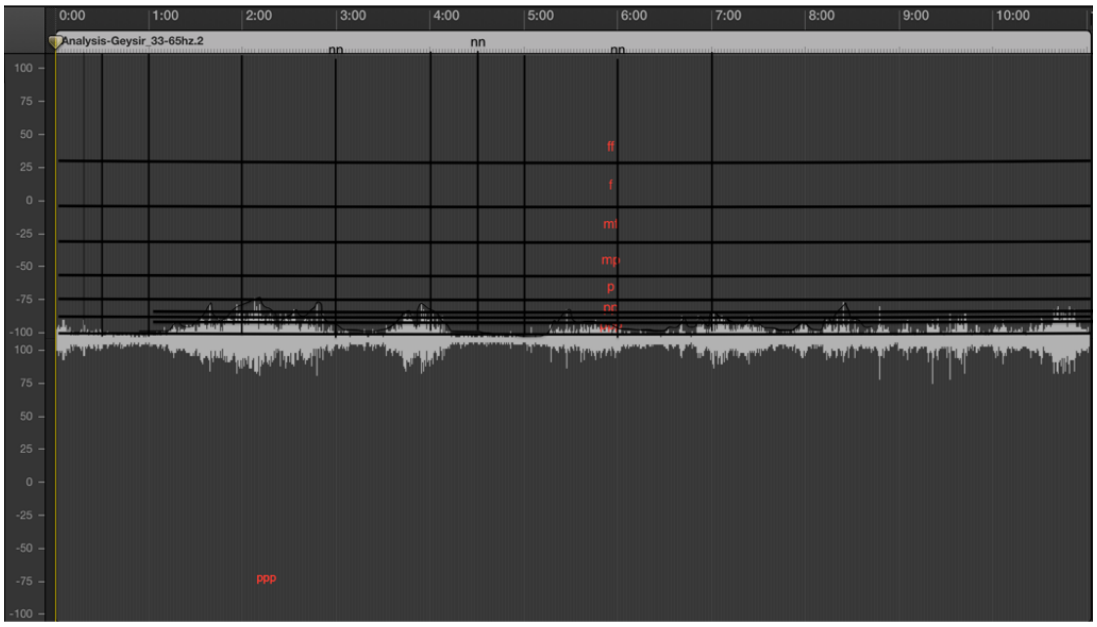
Staff=4 (C4–C5)



Staff=5 (C3–C4)

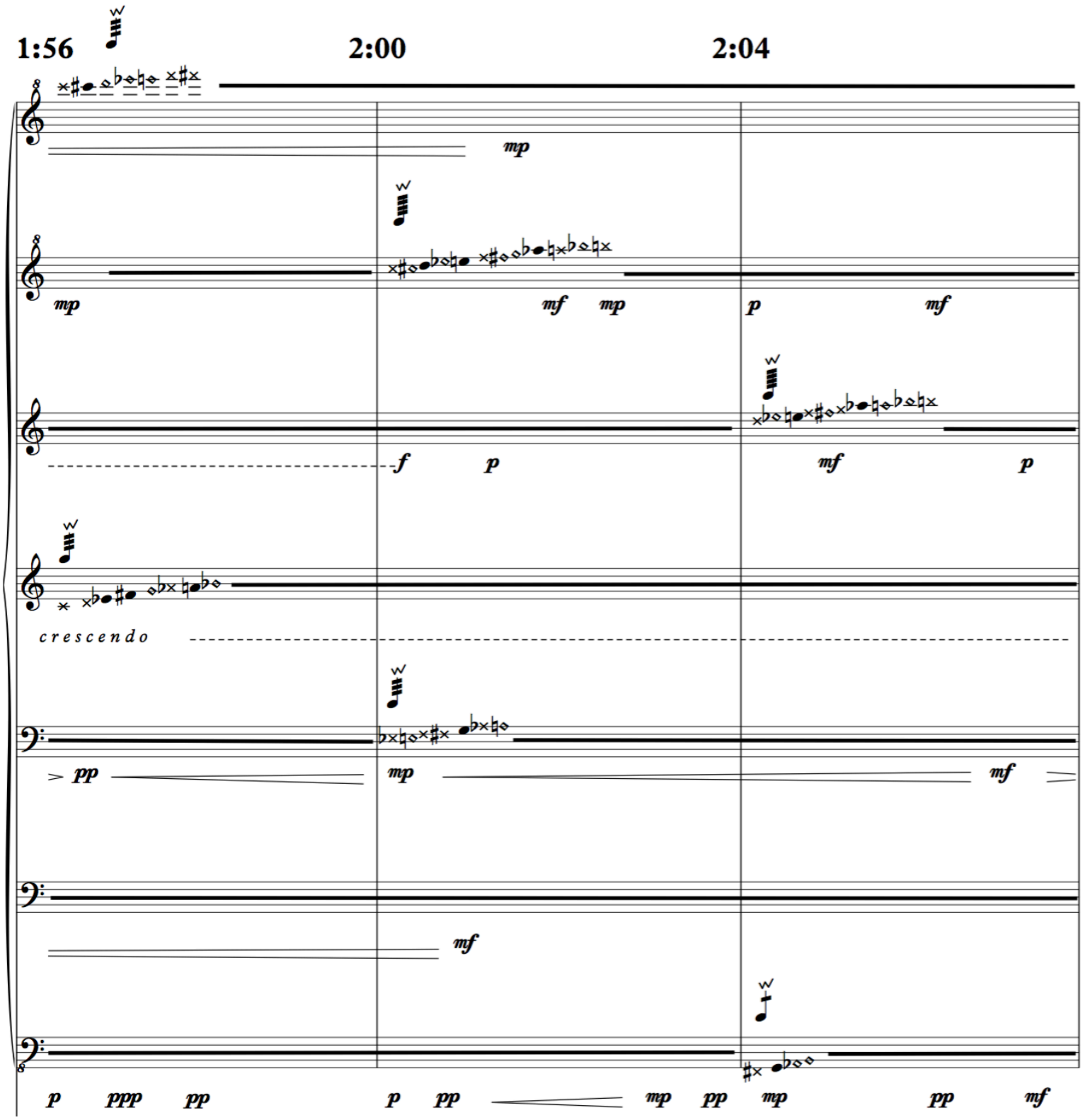


Staff=6 (C2–C3)



Staff=7 (C1–C2)

In the example below, the full score presents one of the overall peaks in amplitude in the entire 11-minute recording. A close look at the dynamics in each of the instruments will show the correspondences both in the macro-level and micro-level of dynamics: while there is a general increase in amplitude from 1:56 to 2:08, there are sudden dips and spikes in the dynamics within the overall increase in the section. The alterations in the dynamics of Staff 1 and 7 are also evident in the example, in which the ***pp*** and ***p***, respectively, are increased to ***mp*** and ***mf*** in order to blend with the dynamics of the rest of the parts.



Full score available at: https://chlunamega.github.io/public/compositions/geysir-composition/Geysir-score.pdf