

ECO-FRIENDLY PRODUCTION OF CALCIUM CARBONATE FROM NATURAL WASTE MATERIALS

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Abstract: The calcium carbonate (CaCO_3) derived from the egg shell of hen and snail shell can be used as fillers in the polymer industries. CaCO_3 was obtained from egg shell and snail shell, this was done by crushing the shell and sieving with a 60 micron mesh. This shell was calcinated in a furnace at $640 \pm 10^\circ\text{C}$ for 2 hours 30 minutes. The powder was characterised by Fourier Transform Infra-Red Spectroscopy (FTIR), Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD). The SEM showed that the CaCO_3 had an irregular shape while the FTIR spectra revealed peaks indicative of the presence of CaCO_3 . The XRD confirmed that CaCO_3 was formed.

Keyword: Calcium carbonate, egg shell, snail shell.

1. INTRODUCTION

Egg and snail shell are important sources of protein for human being. However, their shells are mostly discarded as waste into the environment. The indiscriminate disposal of shell has raised concern for the proper recycling of this waste mostly in third world countries like Nigeria with emerging waste management systems.

Most of the shell waste is deposited in landfills, abandoned on land, or returned to the sea, thereby causing environmental impacts. The waste products when deposited in the soil, contaminate and attract animals due to the strong odour. When dropped in sea, it causes grounding and infects the marine population (Silva, Mesquita-Guimaraes, Henriques, Silva and Fredel, 2019).

CaCO_3 is found in varieties of places like sea shells, calcitic rocks, coral reefs, stalactites and stalagmites formations in the caves (Sever, 2013). Seashell has 95 – 99 % by weight of CaCO_3 which aid its application in quite a number of purposes (Mohamed, Yusup and Maitra, 2012). Kiranda, Mahmud, Abubakar and Zakaria (2018) stated that CaCO_3 as a raw natural mineral has been used in a wide range of applications including biomedical, industrial, and nanotechnology.

Sezer (2013) stated that CaCO_3 is used as filling agents, fillers in paper making industries, sealant, plastic and paint industries. Hamester, Balzer and Becker (2012) reported that CaCO_3 is the most widely used filler in polymer industries. The cheapest grades are used to reduce cost while their finest grades are used to modify various properties. Sasikumar and Vijayaraghavan (2016), stated that egg shells are useless after the utilisation of egg contents and wasted. They informed that egg shells lead to environmental pollution since these favour microbial growth. These wastes according to them are available in huge quantity from food processing industries, egg baking and hatching industries.

2. MATERIALS AND METHODS 2.1 MATERIALS

The materials used included; egg shell, snail shell and distilled water.

2.2 EQUIPMENTS

Equipments used in the research are; electronic weighing scale, beaker, pH paper, filter paper, laboratory furnace, crucible pot, crucible tong, desicator, motar and pestle.

2.3 METHODS

2.3.1 MATERIAL PROCESSING PROCEDURE

The shells were washed, dried and crushed by grinding in a mill. The crushed shells were sieved using a mesh of 60 micron. The sieved shells were calcinated in a laboratory furnace at 640 ± 10 °C for 2 hours 30 minutes. The powders were crushed with motar and pestle and then characterised using FTIR (Fourier Transform Infra-Red Spectroscopy), SEM (Scanning Electron Microscope) and XRD (X-Ray Diffraction).

2.3.2 FOURIER TRANSFORM INFRA- RED SPECTROSCOPY (FTIR)

The FTIR machine model Cary 630 by Agilent Technologies, USA was used, FTIR spectroscopy uses infra-red radiation (IR) beam to identify chemical bonds in a molecule by producing infra-red absorption spectrum. The FTIR spectroscopy was done as per ASTM E168.

2.3.3 SCANNING ELECTRON MICROSCOPY (SEM)

SEM was used to study the surface morphology of the powder and the composition. The SEM model is PhenomProx, a product of Phenom World Eindhoven Netherlands. The SEM analysis was conducted via ASTM E2809.

2.3.4 X-RAY DIFFRACTION (XRD)

The XRD analysis was carried out via ASTM D5357. XRD was used to identify the crystal structure of the powder.

3. RESULT AND DISCUSSION

3.1 FTIR Spectroscopy result

The FTIR spectroscopy revealed calcium (Ca^{2+}) spectra at 1796.6 cm^{-1} , Ca^{2+} peak for egg shell was seen at 2512.2 cm^{-1} while Ca^{2+} peak for snail shell was observed at 2322.1 cm^{-1} . Hydroxyl stretching mode was observed at 3570 cm^{-1} . FTIR spectra for egg shell revealed characteristics peaks for CaCO_3 at 711.8 cm^{-1} and 872.2 cm^{-1} and for snail shell at 711.9 cm^{-1} and 872.2 cm^{-1} .

3.2 Scanning Electron Microscope result

The SEM morphology of both egg and snail shell are irregular in shape. SEM morphology at magnification of 350X showed the egg shell to be $764 \mu\text{m}$ while the snail shell is $766 \mu\text{m}$. For magnification of 500X both egg and snail shell are $536 \mu\text{m}$. At magnification of 1000X egg and snail shell was $268 \mu\text{m}$. At magnification of 1500X both samples are $179 \mu\text{m}$. At magnification of 2000X the two samples was $134 \mu\text{m}$.

3.3 X-ray diffraction result

The XRD revealed that egg shell had CaCO_3 and calcium oxide (CaO) while the snail shell had CaCO_3 .

3.4 DISCUSSION

The SEM morphology of both egg and snail shell were irregular in shape, this is in line with the observed morphology of oyster and mussel shell which was irregular in shape too as seen in the work of Hamester et al., (2012).

Moreover, the XRD result obtained in this research is in agreement with what was obtained by Hamester et al., (2012). Reig, Gimeno-Adelantado and Moya-Moreno (2002) were able to determine the FTIR band for CaCO_3 at 872.2 cm^{-1} and 711.8 cm^{-1} for egg shell and 872.2 cm^{-1} and 711.9 cm^{-1} for snail shell again this agrees totally with our results.

Hamester et al., (2012) reported that the shellfish was milled and heated at 500 °C for 2 hours also in this research the shells (egg and snail) were calcinated to 640 ± 10 °C for 2 hours 30 minutes.

4. CONCLUSION

This research has derived CaCO_3 from egg and snail shell. The CaCO_3 exhibited the properties which were in conformity to those derived from some crustacean shell and other shells. This was revealed by FTIR spectroscopy, SEM and XRD.

ACKNOWLEDGEMENT

We are thankful to the following; the department of Polymer and Textile Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Owerri, A. B. U., Zaira and Engr Dr Henry Opara.

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Agilent Technologies

Sample ID: EGG SHELL

Sample Scans:30

Background Scans:16

Resolution:8

System Status:Good

File Location:C:\Program Files\Agilent\MicroLab PC\Results\ EGG SHELL_2018-09-22T15-58-16.a2r

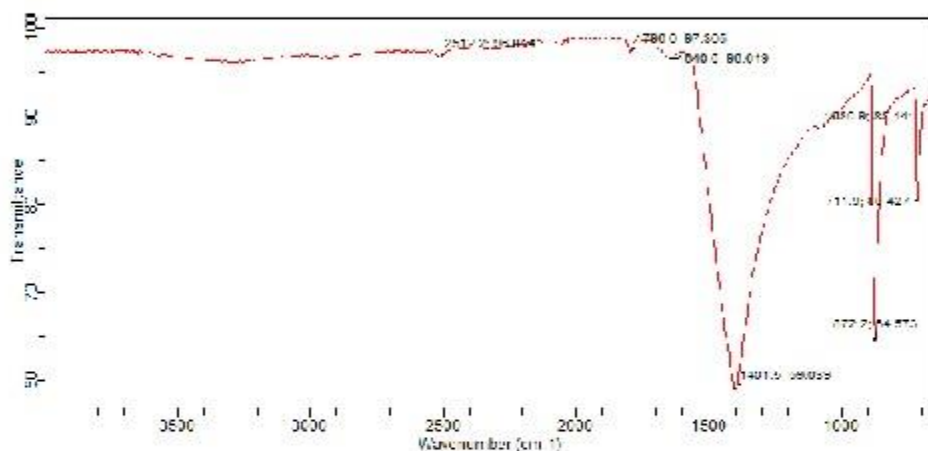
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Apodization:Happ-Genzel



9/22/2018 4:06:19 PM

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Figure 1: FTIR Spectroscopy of Egg Shell



Agilent Technologies

Sample ID: SNAIL SHELL
Sample Scans: 30

Background Scans: 16
Resolution: 8

System Status: Good

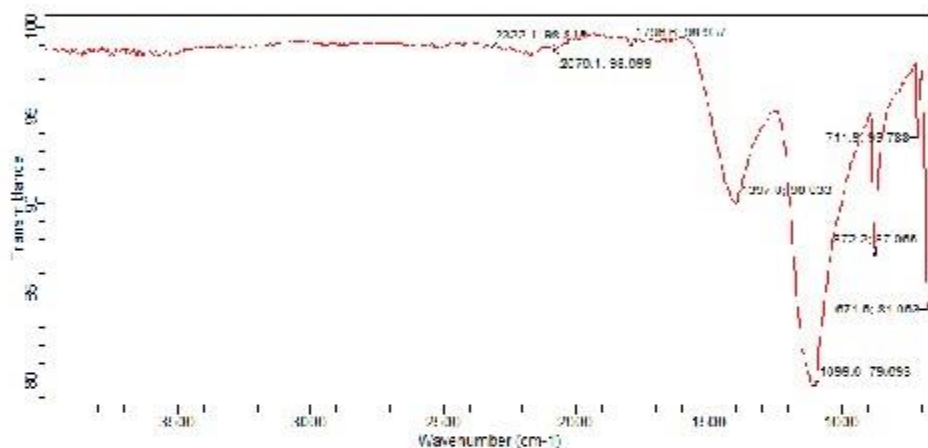
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9/22/2018 5:37:55 PM

page 1 of 1

Figure 2: FTIR Spectroscopy of Snail Shell

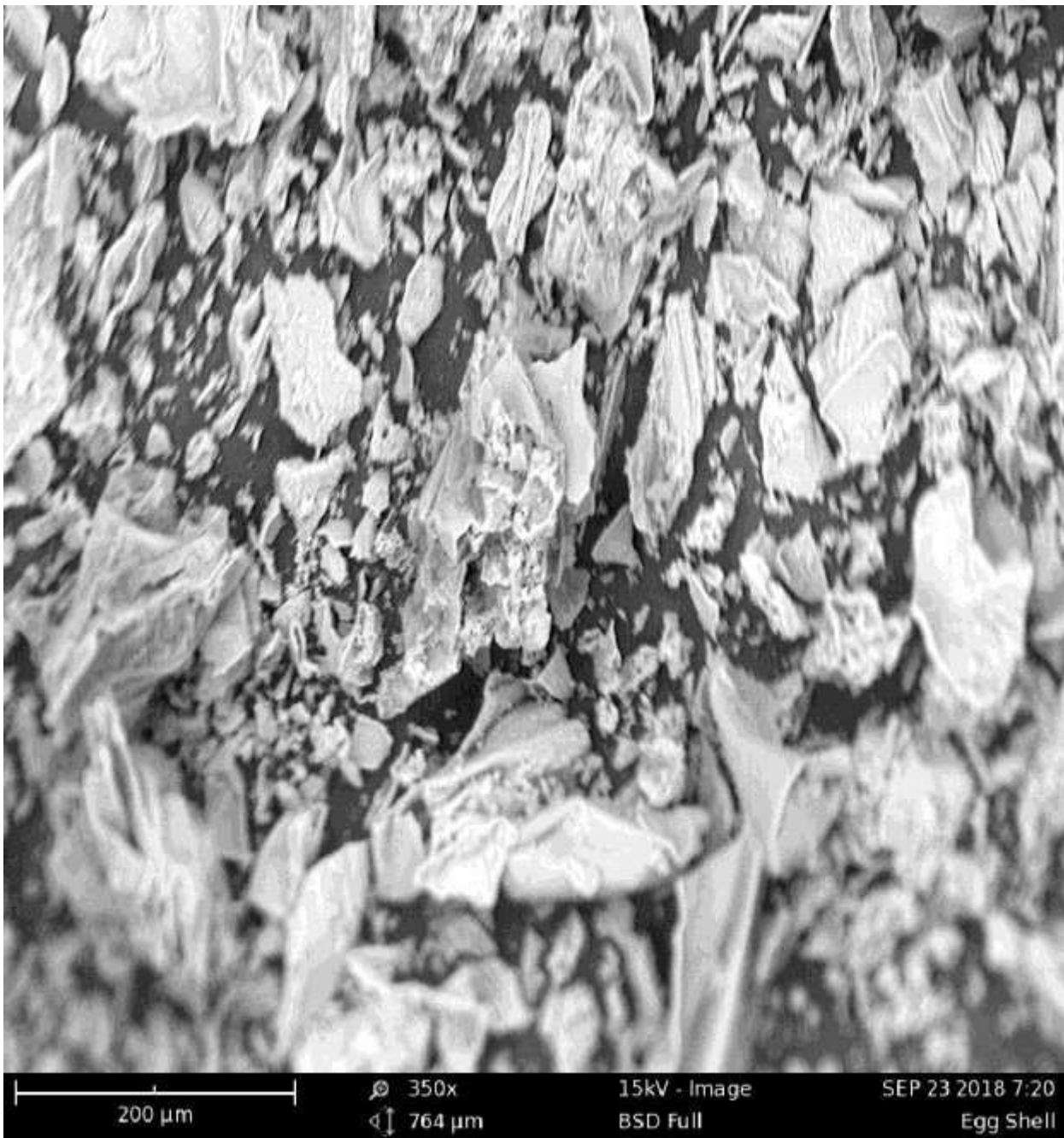


Figure 3: SEM Spectroscopy of Egg Shell at 350X magnification

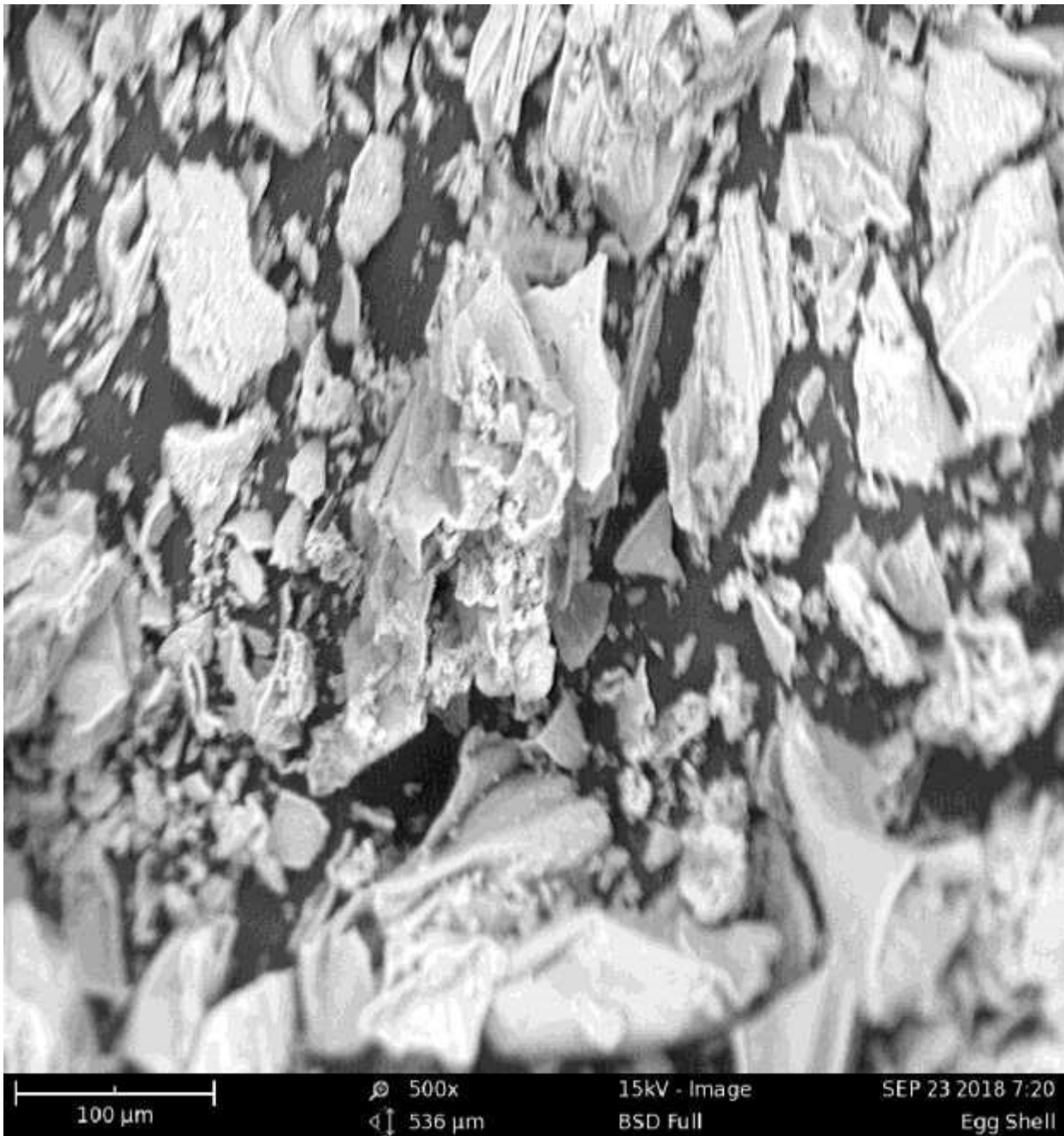


Figure 4: SEM Spectroscopy of Egg Shell at 500X magnification

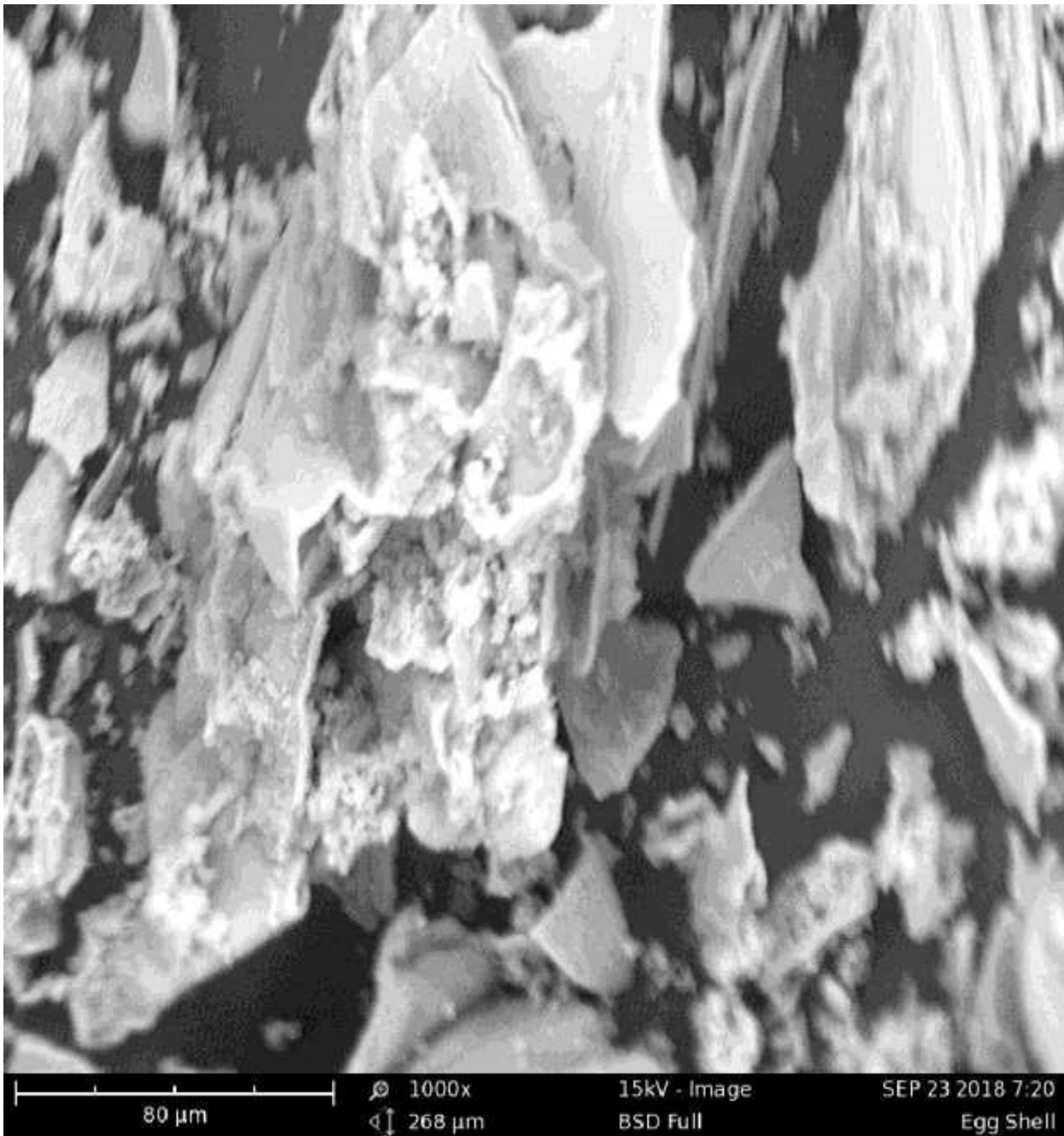


Figure 5: SEM Spectroscopy of Egg Shell at 1000X magnification

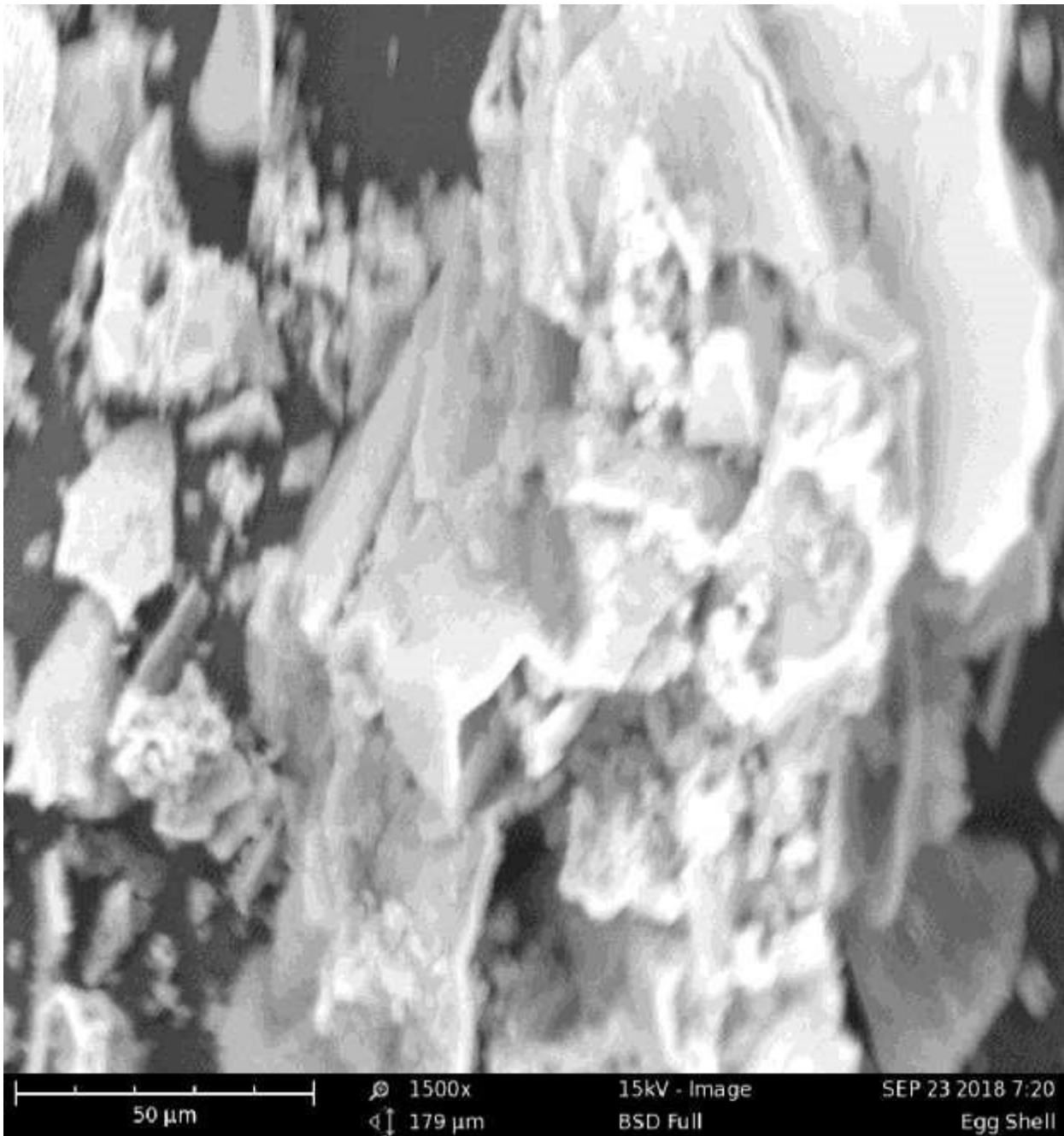


Figure 6: SEM Spectroscopy of Egg Shell at 1500X magnification

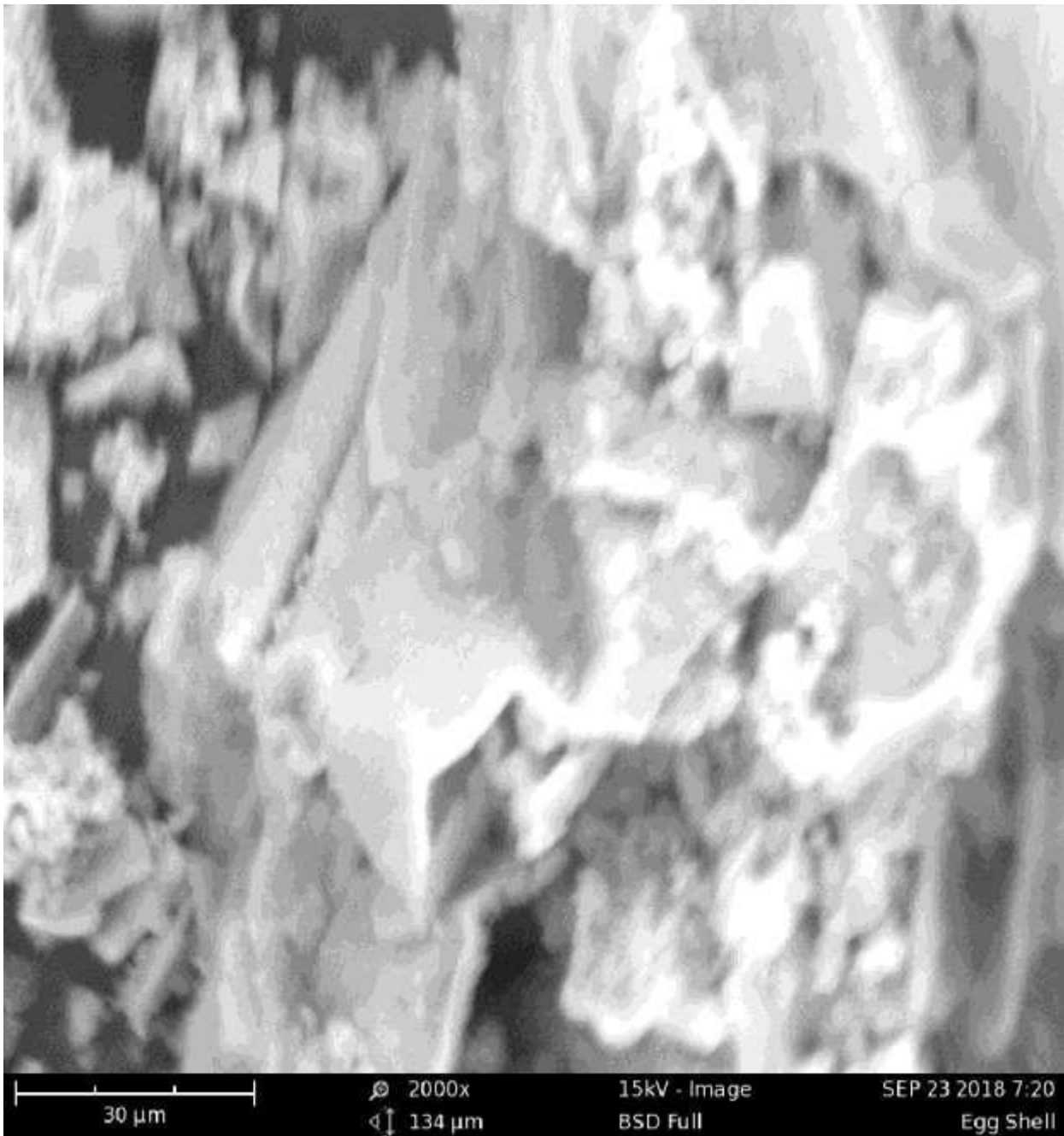


Figure 7: SEM Spectroscopy of Egg Shell at 2000X magnification

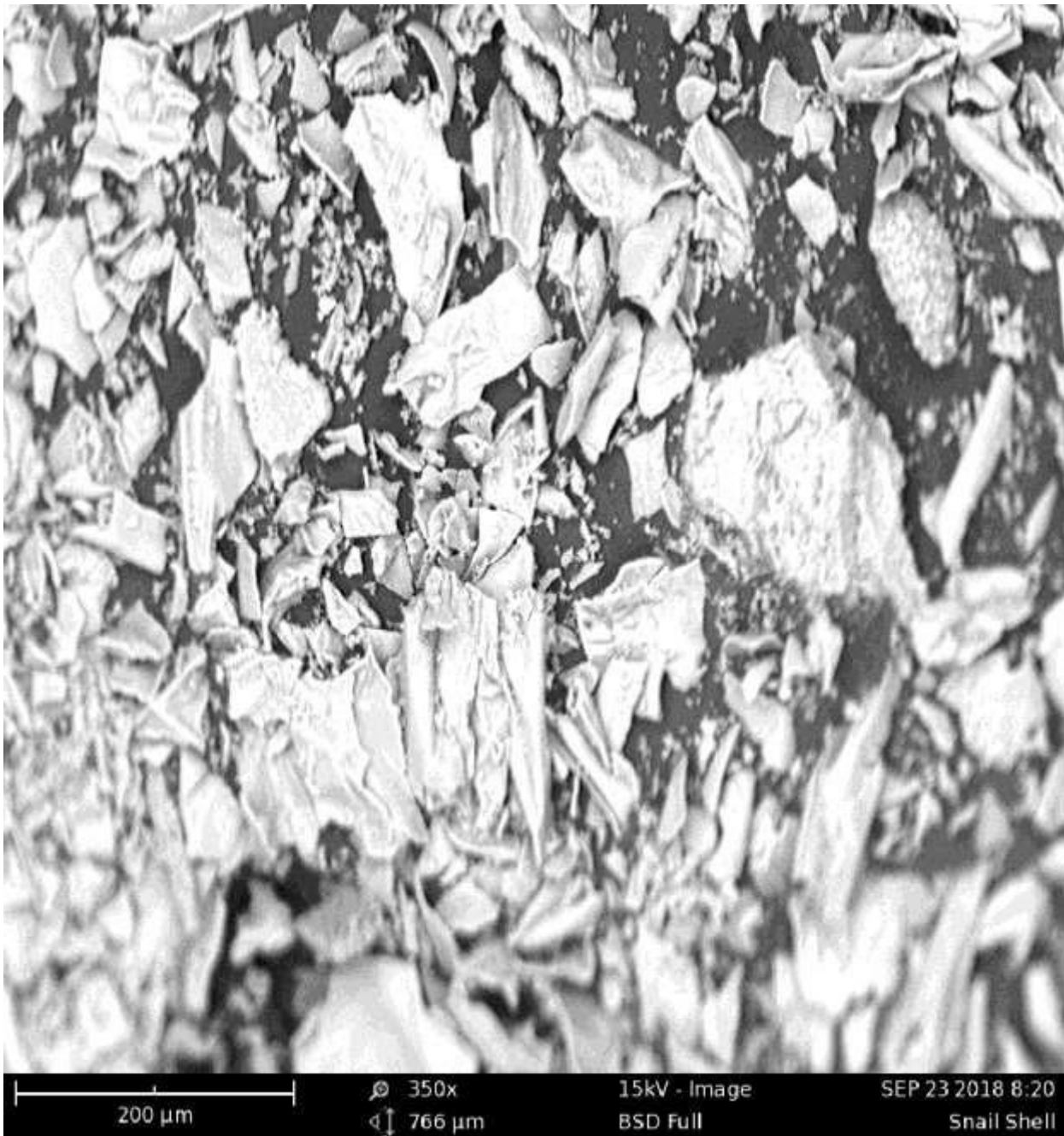


Figure 8: SEM Spectroscopy of Snail Shell at 350X magnification

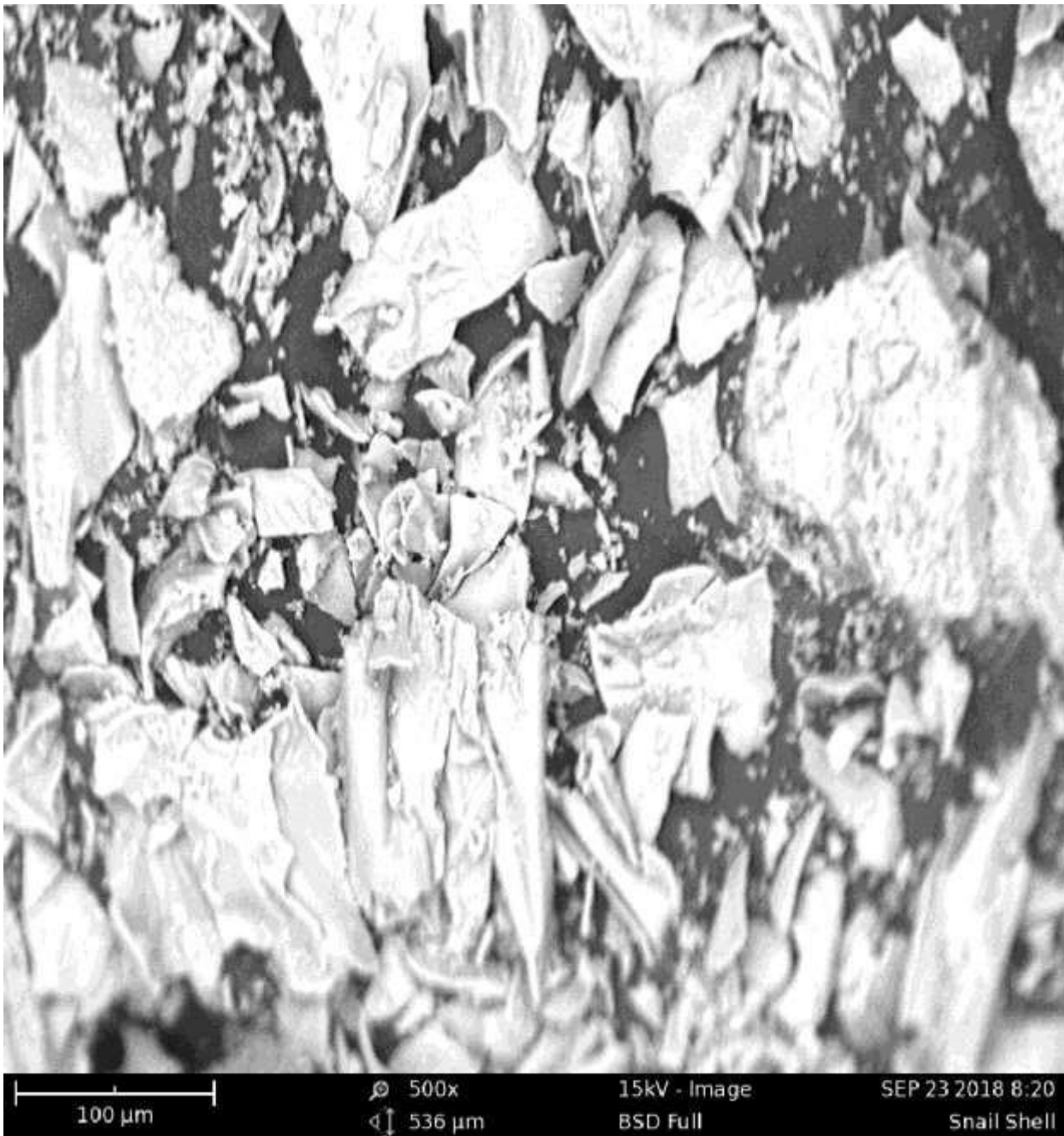


Figure 9: SEM Spectroscopy of Snail Shell at 500X magnification



Figure 10: SEM Spectroscopy of Snail Shell at 1000X magnification

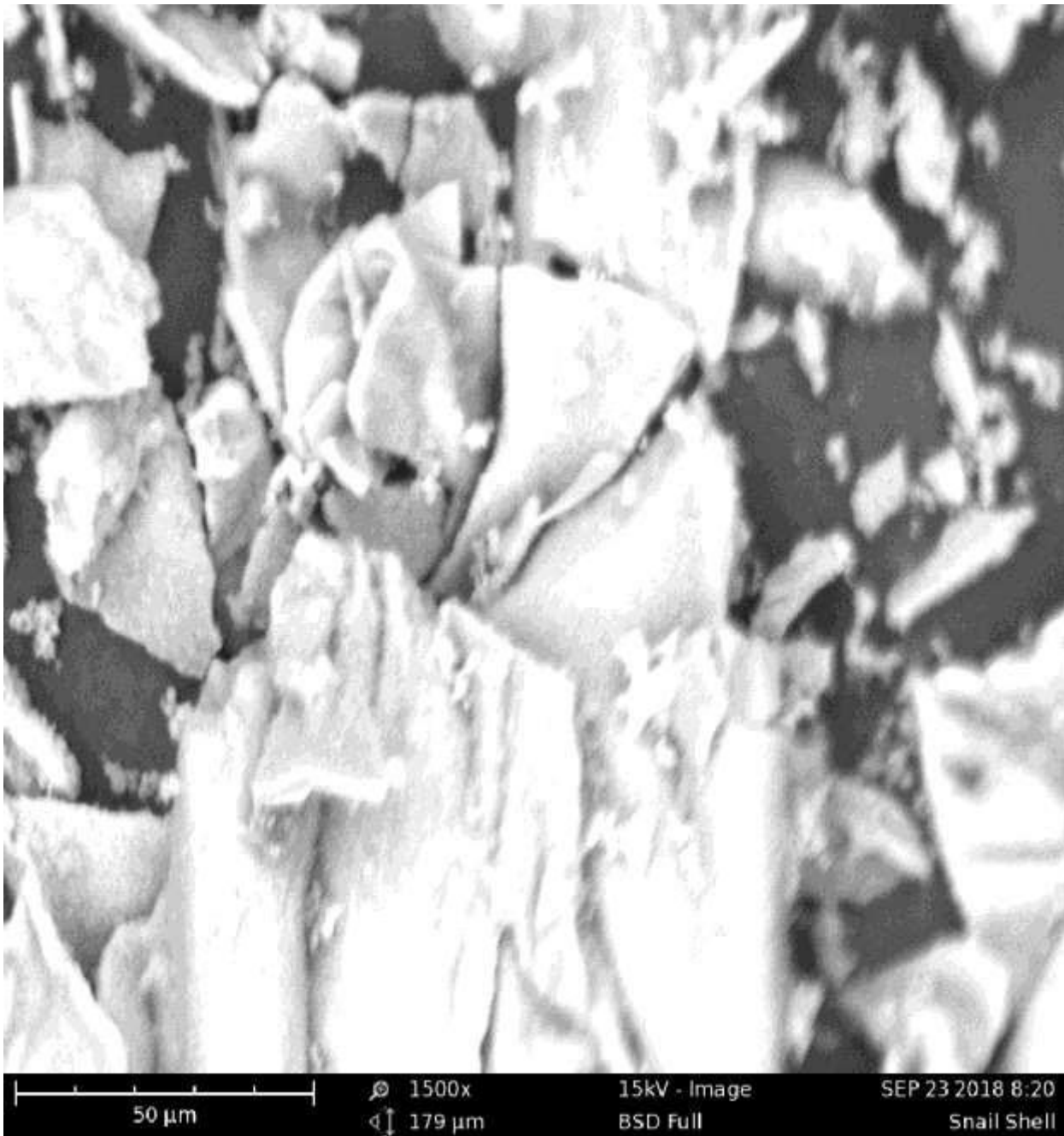


Figure 11: SEM Spectroscopy of Snail Shell at 1500X magnification

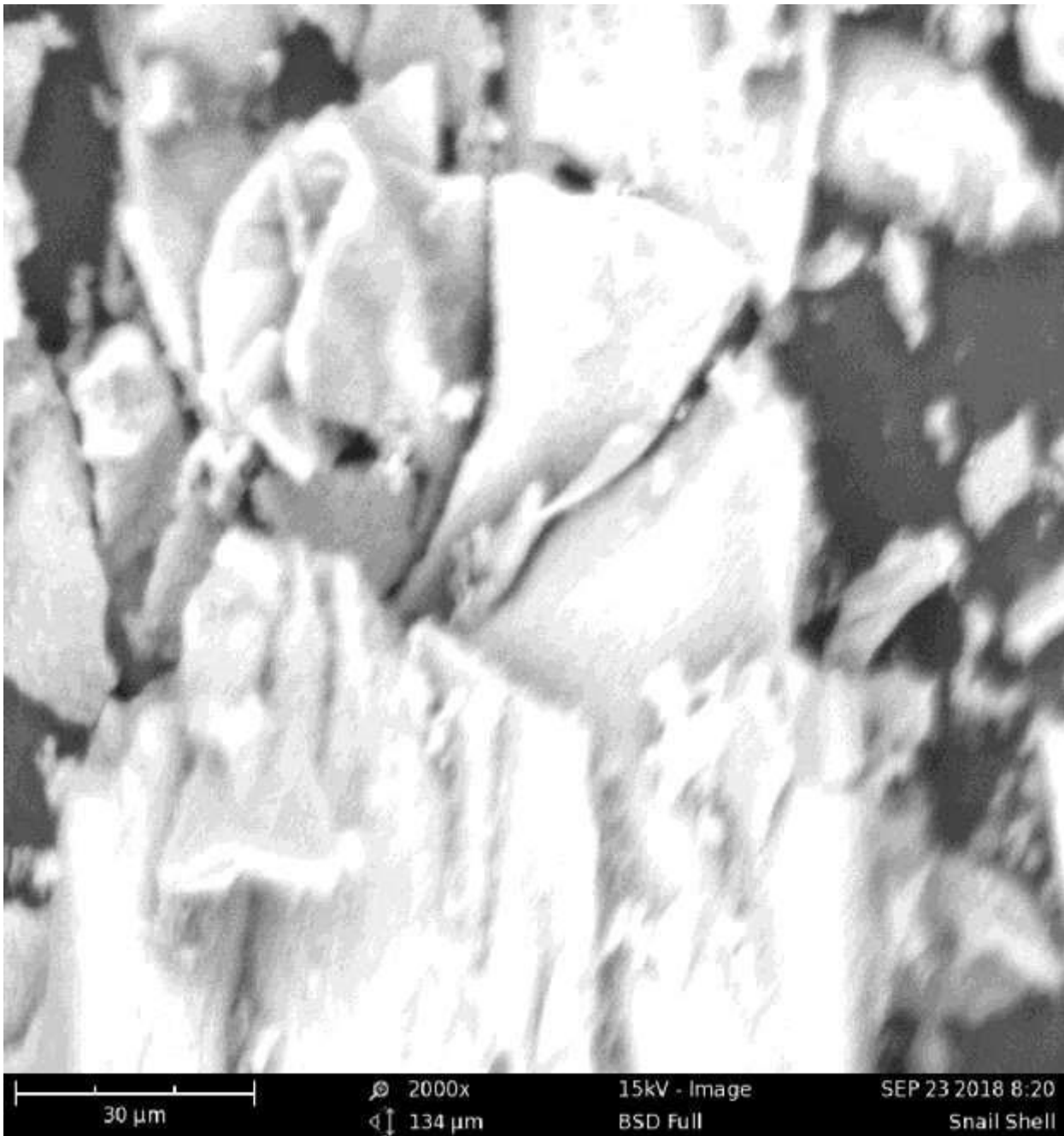


Figure 12: SEM Spectroscopy of Snail Shell at 2000X magnification

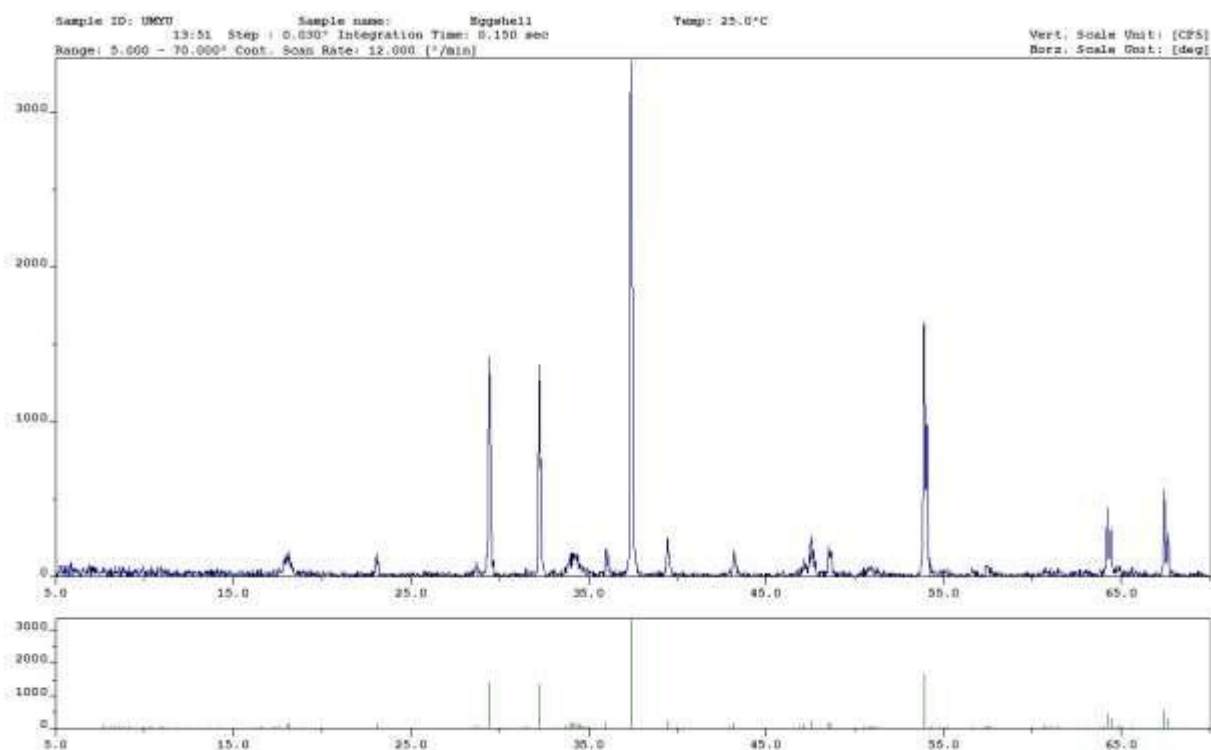


Figure 13: XRD of Egg Shell

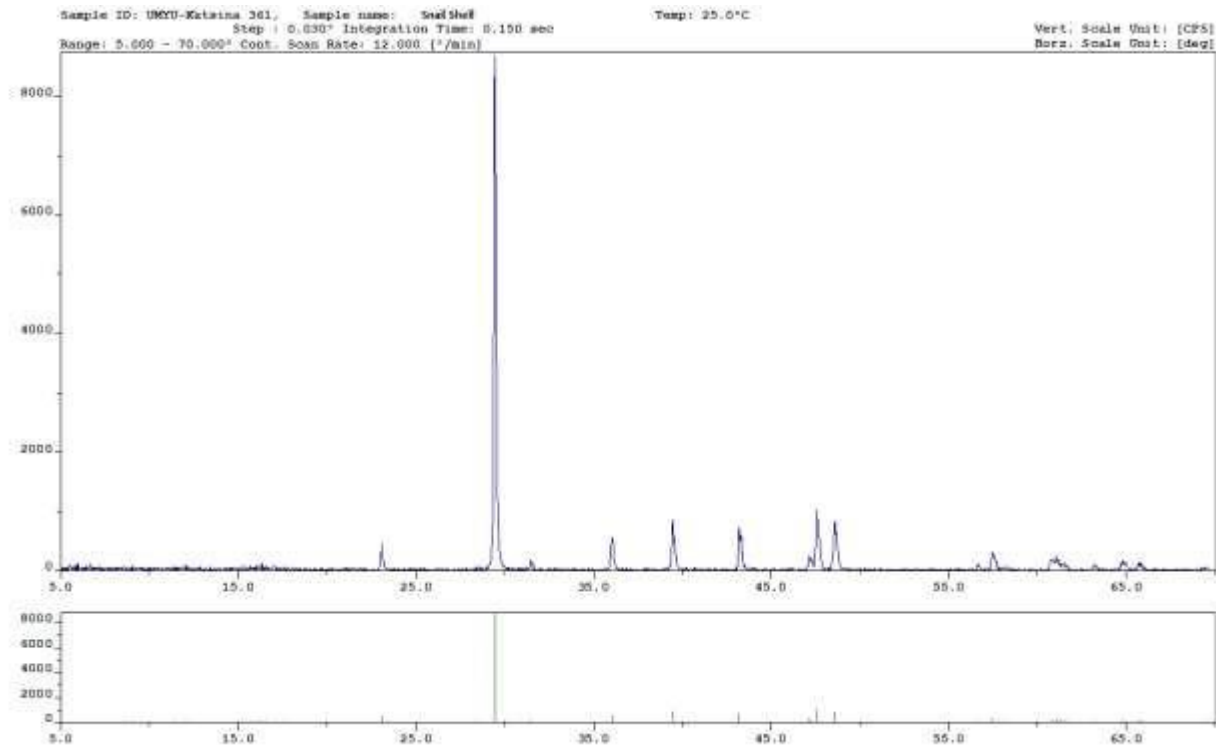


Figure 14: XRD of Snail Shell

Table 2: XRD result of Snail Shell

01-083-0577

Sep 24, 2018 11:03 AM (ARLservice)

Status Alternate QM: Star (S) Pressure/Temperature: Ambient Chemical Formula: Ca (C O3) Weight %: C12.00 Ca40.04 O47.95

Atomic %: C20.00 Ca20.00 O60.00 ANX: ABX3 Compound Name: Calcium Carbonate Mineral Name: Calcite

Radiation: CuKα1 : 1.5406Å d-Spacing: Calculated Intensity: Calculated I/c: 3.21

Reference: "Datensammlung nach der 'Learnt profile'-Methode(LP) fuer Calcit und Vergleich mit der 'Background peak background'-Methode (BPB)". Warchow, R. Z. Kristallogr. 186, 300 (1989). Calculated from ICSD using POWD-12++. (2004).

SYS: Rhombohedral SPGR: R-3c (167) AuthCellVol: 367.54 Z: 6.00

Author's Cell [AuthCell-a: 4.9887(1)Å AuthCell-b: 4.989Å AuthCell-c: 17.05289(80)Å AuthCellVol: 367.54Å³] Dcalc: 2.713g/cm³ Dstruc: 2.71g/cm³

SI/FOM: F(30) = 999.9(0.0000, 30) R-factor: 0.018 Reference: Ibid.

Space Group: R-3c (167) Z: 6.00 Molecular Weight: 100.09

Crystal Data [XtiCell-a: 4.989Å XtiCell-b: 4.989Å XtiCell-c: 17.053Å XtiCell: 90.00° XtiCell: 90.00° XtiCell: 120.00° XtiCellVol: 367.54Å³]

Crystal Data Axial Ratio [c/a: 3.4183]

Reduced Cell [RedCell-a: 4.989Å RedCell-b: 4.989Å RedCell-c: 6.372Å RedCell: 66.96° RedCell: 66.96° RedCell: 60.00° RedCellVol: 122.51Å³]

Crystal (Symmetry Allowed): Centrosymmetric

CAS: 13397-26-7 Pearson: hR10.00

Subtle(s): Alternate Pattern, Cement and Hydration Product, Common Phase, Forensic, ICSD Pattern, Inorganic, Mineral Related (Mineral), Pharmaceutical (Excipient), Pigment/Dye, Superconducting Material

Entry Date: 12/25/2004 Last Modification Date: 01/31/2008 Cross-Ref PDF #s: 00-005-0586 (Primary), 01-085-1108 (Alternate)

Database Comments: Additional Patterns: See PDF 00-005-0586 and 01-085-1108. ANX: ABX3. Analysis: C1 Ca1 O3. Formula from original source: Ca (C O3). ICSD Collection Code: 79673. Calculated Pattern Original Remarks: Refinement by the 'Learnt Profile' method. Wyckoff Sequence: e b a (R3-CH).

01-083-0577 (Fixed Site Intensity) - Cu K1 1.54056Å													
2	d(Å)	I	h	k	l	*	2	d(Å)	I	h	k	l	*
23.0590	3.853850	99	0	1	2		70.2675	1.338480	19	0	2	10	
29.4094	3.034550	999	1	0	4		72.9140	1.296290	26	1	2	8	
31.4499	2.842150	19	0	0	6		73.6847	1.284620	6	3	0	6	
35.9750	2.494350	139	1	1	0		76.2853	1.247170	11	2	2	0	
39.4169	2.284110	176	1	1	3		77.1935	1.234750	19	1	1	12	
43.1661	2.094010	149	2	0	2		78.4414	1.218200	1	2	2	3	
47.1247	1.926920	64	0	2	4		80.2450	1.195300	1	1	3	1	
47.5255	1.911600	185	0	1	8		80.9555	1.186590	5	3	1	2	
48.5191	1.874750	194	1	1	6		81.5525	1.179410	21	2	1	10	
55.5720	1.525500	31	2	1	1		82.1478	1.172360	3	0	1	14	
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61.3970	1.508810	24	1	1	9		91.5151	1.075220	1	1	3	7	
63.0666	1.472830	19	1	2	5		91.9219	1.071520	1	0	4	2	
64.6709	1.440110	57	3	0	0		93.1022	1.061010	8	2	0	14	
65.6455	1.421070	31	0	0	12		94.7317	1.047010	23	4	0	4	
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							103.5650	0.980413	3	1	3	10	
							104.1720	0.976353	9	1	2	14	
							105.9560	0.965407	9	3	2	4	
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							107.3950	0.955799	5	0	2	16	
							108.0560	0.951777	2	2	3	5	
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							110.5200	0.937373	9	2	2	12	
							111.8280	0.930070	1	4	1	3	
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							115.1690	0.912460	1	4	0	10	
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							118.8150	0.894830	6	1	4	6	
							119.3200	0.892519	10	2	1	16	
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							132.9260	0.840180	1	2	2	15	
							134.0940	0.836509	7	0	1	20	
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							138.8740	0.822896	1	3	3	3	
							141.6470	0.815533	1	2	4	1	
							142.7920	0.812750	7	4	2	2	
							144.7880	0.808134	1	0	4	14	
							147.7160	0.801894	6	2	4	4	

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