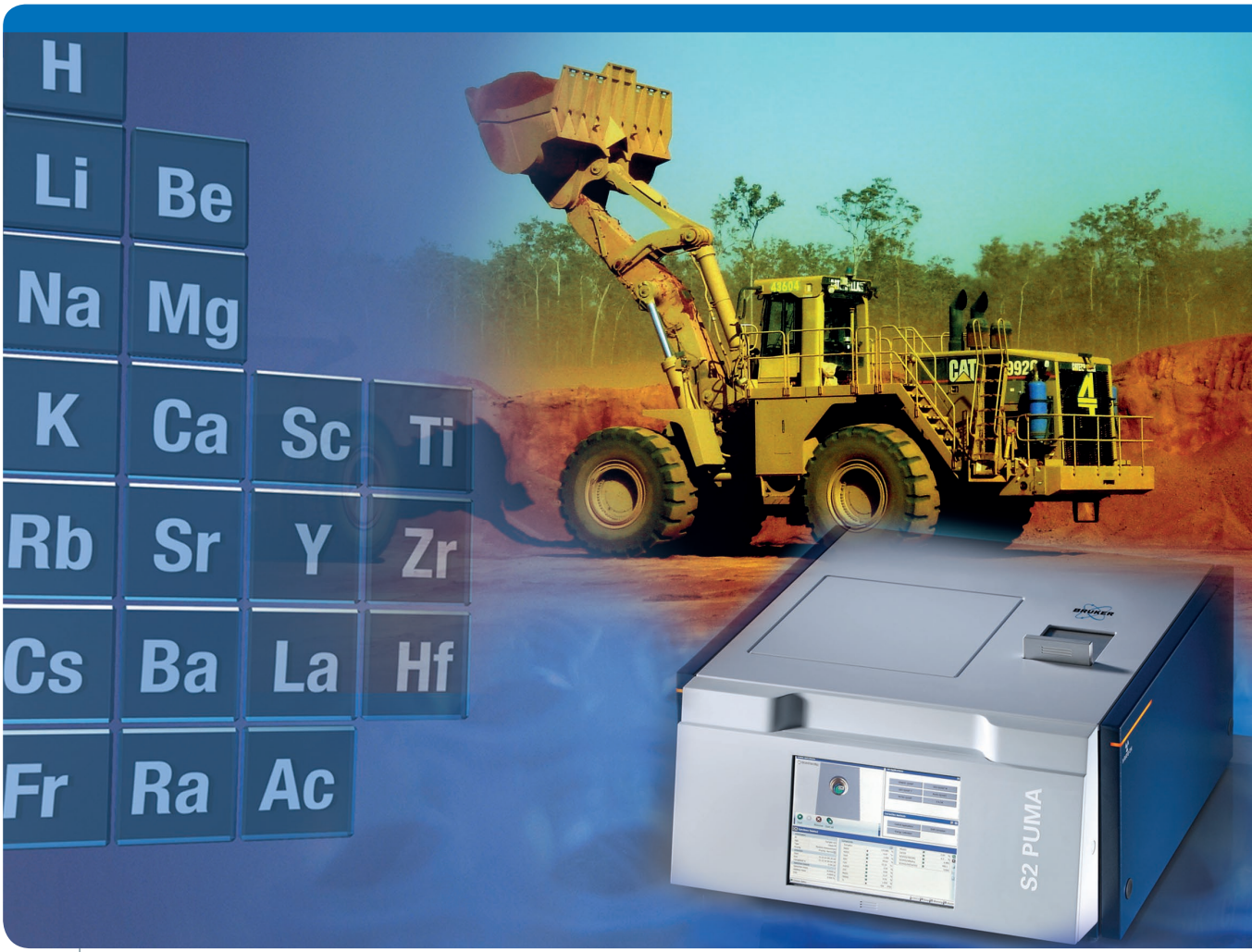


S2 PUMA for Analysis of Geological Materials

- Precise and Reliable Grade Control of Geological Materials

EDXRF

Innovation with Integrity

Maximizing Your Process Yield and Improve Material Grades with S2 PUMA

Precise and reliable grade control is the key to optimize process yield

The analysis of a wide range of geological materials are covered with the S2 PUMA such as:

- Feldspar
- Clay
- Dolomite
- Limestone
- Phosphate
- Bauxite
- Silica
- Gypsum
- Magnesite
- Iron ore
- Nickel laterite
- Your Material

Process steps in mining operations are already optimized to a very high degree. But with fast and reliable information about the elemental composition of the geological material and their intermediate products, such processes can be further optimized. Therefore, fast and reliable grade control of geological material is essential to maximize the process yield.

S2 PUMA for Geological Materials – the Perfect Fit for Better and Quicker Results

The S2 PUMA is a ruggedized, benchtop energy dispersive X-ray spectrometer developed for highly accurate grade control of geological materials.

Simple sample preparation makes XRF the fastest and most practical method for all applications in mining. And the S2 PUMA with its ideal configuration for all relevant elements in mining delivers the required analytical accuracy and precision. It enables the close control of the mining operation in order to achieve cost efficiency and realize dramatic cost savings. This all comes in handy with a low cost of ownership.

S2 PUMA Single for quick grade control of geological samples

Measurement Parameters

Measurements were performed on an S2 PUMA with HighSense™ LE silicon drift detector (SDD) and the X-ray tube with Ag anode. The HighSense™ LE detector is equipped with an ultrathin, high transmission entrance window that enhances the sensitivity for light elements (LE) such as Na and Mg. Ideal for geological materials is the analysis under vacuum, since it combines optimal sensitivity for all elements with low running costs and less installation requirements, since no gas flushing is required. Table 1 shows the measurement conditions for all elements analyzed. The tube current is set automatically by our DynaMatch technology to enable output count rates as high as 300 kcps. At this count rate, the HighSense™ LE detector operates at fastest speeds whereby maintaining its energy resolution.

The overall processing time per sample, including sample handling, evacuating the sample chamber and actual counting time for the measurement, is typically less than 5 minutes.

Geological samples prepared as fused beads ensure a wide concentration range for the calibration

Geological samples prepared as pressed pellets ensure fast availability of the analytical results

Samples Prepared as Fused Beads – for Best Results Over a Wide Calibration Range

The standards were prepared as fused beads. This preparation method avoids mineralogical and grain size effects, which especially may effect light element determination. As the mineralogical structure of the standard is broken down during the fusion process, many different mineral types can be used to form a single calibration. This means that a single calibration can cover a wide concentration range. The fused beads were prepared by using 1.1 g standard or sample material and 6.9 g lithium tetraborate. Different geological samples used for the precision tests were prepared in the same way.

Samples Prepared as Pressed Pellets – for Fast Feedback of the Chemical Composition

Controlling the mining process often requires a fast feedback of the chemical composition. Therefore the time between collecting a sample and obtaining the analytical result should be as short as possible. In such case, the geological samples are prepared as pressed pellets. When compared with the preparation of fused beads, this method simplifies and shortens the sample preparation time considerably, meaning that the results are available sooner after the sample has been collected.

Table 1: Optimal measurement conditions for geological samples on the S2 PUMA

Voltage [kV]	Beam filter	Measurement time [s]	Elements analyzed
20	No Filter	100	Na, Mg, Al, Si, P, S
40	500 µm Al	100	K, Ca, Ti, Mn, Fe

A set of 20 geological certified reference materials (CRM) were used to establish a wide calibration range. This set of CRMs covers different geological materials from feldspar to gypsum. In addition, the set contains 3 validation standards for checking the quality of the calibration. The standards cover the 11 most important elements for the analysis of major and minor elements as oxides in geological materials. The following elements are included in the evaluation: Na_2O, MgO, Al_2O_3, SiO_2, P_2O_5, SO_3, K_2O, CaO, TiO_2, Mn_2O_3 and Fe_2O_3. The concentration ranges covered with the calibration are shown in Table 2.

As an example, the calibration curve for the oxide MgO is shown in Figure 1.

Table 2: Concentration range covered with certified reference materials (CRMs)

Oxide	Min. concentration [%]	Max. concentration [%]
Na_2O	0.02	11.3
MgO	0.02	95.8
Al_2O_3	0.04	90.8
SiO_2	0.7	99.9
P_2O_5	0.01	19.3
SO_3	0.02	54.4
K_2O	0.01	15.4
CaO	0.01	97.9
TiO_2	0.01	7.8
Mn_2O_3	0.01	0.9
Fe_2O_3	0.01	39.0

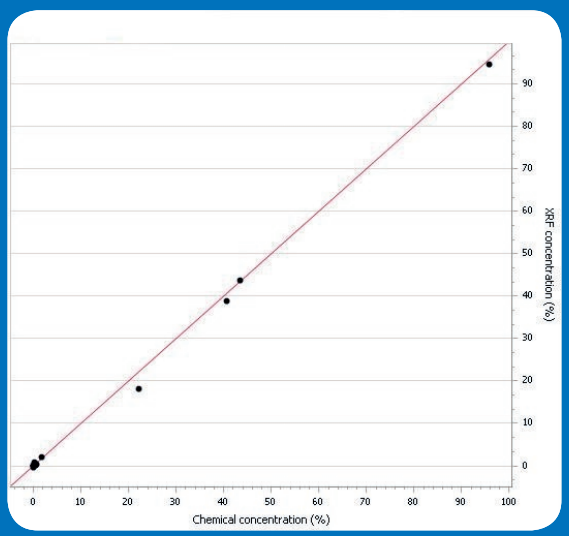


Figure 1: Calibration curve from 0.02 % to 96 % MgO

S2 PUMA XY Autochanger for fully autonomous analysis of larger sample batches

Measurement Accuracy and Precision

Measurements of unknown samples were evaluated against the established calibration curves. The measured concentration showed an excellent agreement with the expected data. Furthermore precision tests have been performed to prove the repeatability of the instrument. Therefore 20 replicates of the same sample were measured and the repeatability is shown in Table 3.

Table 3: Precision test of a feldspar sample

Sample	Na_2O [%]	MgO [%]	Al_2O_3 [%]	SiO_2 [%]	P_2O_5 [%]	SO_3 [%]	K_2O [%]	CaO [%]	TiO_2 [%]	Mn_2O_3 [%]	Fe_2O_3 [%]
Rep-01	1.85	18.51	6.80	28.27	0.72	0.49	3.72	31.46	0.30	0.50	4.46
Rep-02	1.82	18.69	6.95	28.62	0.73	0.49	3.37	31.07	0.33	0.52	4.46
Rep-03	1.84	18.55	6.72	28.46	0.73	0.50	3.56	31.10	0.29	0.52	4.46
Rep-04	1.89	18.46	6.80	28.46	0.72	0.49	3.91	31.19	0.27	0.52	4.46
Rep-05	1.84	18.57	6.91	28.52	0.73	0.51	3.42	31.11	0.28	0.51	4.42
Rep-06 - 15	…	…	…	…	…	…	…	…	…	…	…
Rep-16	1.83	18.55	6.810	28.56	0.71	0.48	3.62	31.26	0.29	0.52	4.48
Rep-17	1.74	18.36	6.92	28.58	0.73	0.50	3.70	30.78	0.29	0.50	4.43
Rep-18	1.74	18.34	6.79	28.34	0.72	0.49	3.33	31.26	0.27	0.51	4.41
Rep-19	1.84	18.68	6.77	28.56	0.70	0.49	3.41	31.18	0.30	0.51	4.42
Rep-20	1.76	18.50	6.86	28.54	0.73	0.49	3.29	30.98	0.27	0.51	4.39
Mean value	1.823	18.53	6.84	28.50	0.727	0.495	3.56	31.15	0.293	0.508	4.44
Abs. std. dev.	0.043	0.105	0.065	0.114	0.012	0.010	0.181	0.254	0.017	0.010	0.026
Rel. std. dev. [%]	2.38	0.57	0.94	0.40	1.59	2.07	5.07	0.82	5.92	1.93	0.59

Results

For all relevant elements in geological materials the typical standard deviation is less than 2 % and even below 1 % for majors. Due to the higher dilution of fused beads the precision can be optimized using pressed pellet preparation in order to enhance the precision for specific materials. Based on S2 PUMA the grade of geological material is quickly determined.

EDXRF Made Easy, Only With S2 PUMA and TouchControl™

Thanks to TouchControl™, the operation of the S2 PUMA is easy and straightforward – no special training required and no manual to read! With TouchControl™, any user can perform measurement jobs on the S2 PUMA. First, select the application and enter the sample ID. You can also add additional information, like preparation or sample weight if required. Then simply start the measurement and view the results on the screen. But it gets even easier: For routine QC-type work, you just have to press the button once – this starts a predefined automatic application – and that's it!

S2 PUMA with TouchControl™:

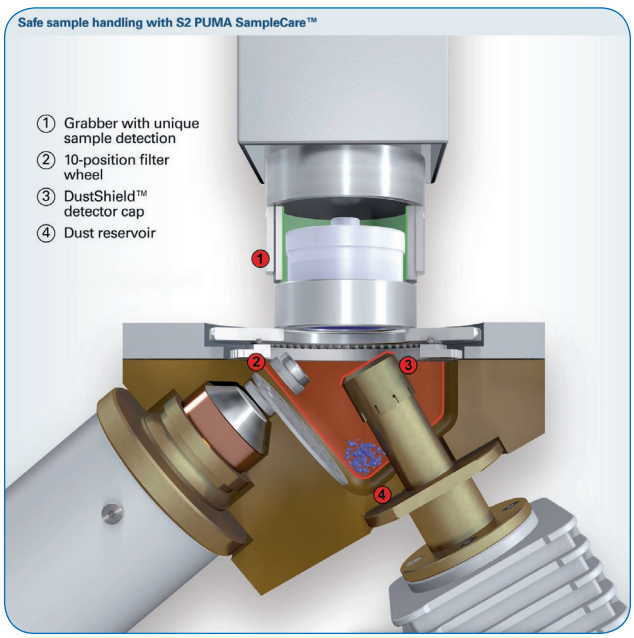
- Intuitive, failsafe ease-of-use
- Free language selection:
  English, German, French, Spanish, Portuguese, Italian, Russian, Chinese, Japanese
- Minimal training required – get results quickly from day one
- Adjustable touchscreen, glove-friendly

Island mode: No PC, keyboard and mouse required for routine operation

S2 PUMA – Elemental Analysis Couldn't be Easier!

EDXRF Made Easy, Only With S2 PUMA

Energy-dispersive X-ray fluorescence (EDXRF) with the S2 PUMA offers all you need to measure and monitor elements in your geological samples. The strength of EDXRF is the wide range of elements covered by the technique, from very light elements like carbon (C), to heavy elements such as americium (Am).



S2 PUMA with SampleCare™: Unique contamination protection of important system components guarantees highest instrument uptime

S2 PUMA With HighSense™ – the Top-performing EDXRF for Geological Material

Instrument precision is the key for precise and accurate grade control. The S2 PUMA delivers excellent precision with its HighSense™ technology, the 50-Watt power of the X-ray tube and unique closely coupled beam path. This superior stability guarantees grade control at its best even with a very narrow range for the results, minimizing waste and maximizing yield in your process.

Unmatched detection limits, precision and speed in EDXRF by HighSense™ technology:

- Direct-excitation, closely coupled beam path
- X-ray tube with up to 50 W power and 50 kV excitation
- Optimal Light Element (LE) configuration with HighSense™ LE detector

DustShield™ prevents contamination of the detector head and makes for easy cleaning

Technical Data

	S2 PUMA Single	S2 PUMA XY Autochanger	S2 PUMA Carousel
Element range	Sodium to americium (Na – Am) Carbon to americium (C – Am) with light element (LE) detector		
Concentration range	From ppm to 100 %		
X-ray tube	Pd or Ag anode; max. power 50 W; max. voltage 50 kV (low kV version: 30 kV max.)		
Primary beam filters	10-position automatic filter changer for wide range elemental analysis		
Detector	Silicon Drift Detector: Peltier cooled (no need for liquid nitrogen) with DustShield™; Also available as fast HighSense™ LE version with super-high count rates		
Collimator Masks*	For small spot analysis: 1, 3, 8, 12, 18, 23 and 28 mm		
Sample Observation*	Integrated HD video camera, for exact sample positioning and documenting the measurement position of a sample		
Atmosphere Mode	Air mode: For heavier elements in all sample types Helium mode*: Best performance for light elements in liquids and loose powders Nitrogen mode*: Cost-saving analysis of liquid samples Vacuum mode*: Enhanced light elements performance for stable samples and lowest cost of operation		
TouchControl™	Integrated 12.1" TFT touchscreen, adjustable, multilingual user interface, optional		
Connectivity	Built-in Ethernet port RJ45, 3x USB ports for mouse, keyboard, printer		
Power Requirements	100-240 V, 50/60 Hz, max. power consumption 600 VA		
Sample Types	Loose powders, granules, solids, pressed pellets, fused beads, and liquids		Loose powders, granules, solids, pressed pellets, fused beads, liquids and bulk samples
Sample Rotation*	Spins all sample types and sizes for better measurement statistics with inhomogenous samples		
Sample Sizes	Up to 51.5 mm (2.03") Ø; Liquids, loose powders, and smaller samples in liquid cups up to 50 ml	Up to 40 mm (1.56") Ø and 38 mm (1.49") height in sample holders with max. 200 g sample weight, or 51.5 mm Ø as sample ring; Liquids, loose powders, and smaller samples in liquid cups up to 20 ml	32, 40, or 51.5 mm (1.26", 1.56", or 2.03") Ø; Liquids, loose powders, and smaller samples in liquid cups up to 50 ml; Bulk samples (max. width x depth x height): 455 x 425 x 106 mm (17.9 x 16.7 x 4.2")
Sample Loader	Single position, manual loading	EasyLoad™ XY sample tray with 20-positions, removable; Grabber with automatic liquid sample detection	EasyLoad™ Carousel sample tray with 12 positions, removable to make room for bulk samples
Dimensions (width x depth x height); Weight	67 x 71 x 37 cm; 87 kg (26.2 x 27.8 x 14.6"; 192 lbs)	67 x 71 x 61 cm; 108 kg (26.2 x 27.8 x 23.8"; 238 lbs)	67 x 71 x 57 cm; 130 kg (26.2 x 27.8 x 22.2"; 287 lbs)
Quality & Safety	DIN EN ISO 9001:2008 2006/42/EC (CE-certified Machinery directive) 2014/35/EC (Electrical equipment) 2014/30/EC (Electromagnetic Compatibility) German Type Approval and Vollschutz according to BfS RöV Fully radiation-protected system; radiation <1 µSv/h (H*) Compliant to ICRP, IAEA, EURATOM		

* optional packages

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