Studies of primary fragmentation using SEM-BSE images of juvenile particle cross-sections: image preparation in Adobe Photoshop©

In: The PArticle Shapes and Textures Analyzer (PASTA) project, version 3.8 (January 24, 2023)
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Link for download: https://doi.org/10.5281/zenodo.3336335

Introduction

The PArticle Shapes and Textures Analyzer (PASTA) project allows to prepare and process SEM-BSE images of juvenile pyroclast cross-sections for magma fragmentation studies in volcanology. It consists of i) a semi-automated image preparation in Adobe Photoshop, as described in the current user guide, and ii) processing and measurement of shape factors, 2D crystallinity and 2D vesicularity in Fiji (ImageJ), using the PASTA script, as described elsewhere.

Before shape factors and internal textures can be determined on Scanning Electron Microscope (SEM)-Backscattered Electron (BSE) images of juvenile particle cross-sections, there is a stage of preparing the multi-particle images in Adobe Photoshop© (Comida et al. 2022; Ross et al. 2022). The goals of image preparation are to:

(1) keep only the juvenile particles not touching the edges, while making sure that the juvenile particle outlines are perfectly selected;
(2) replace the inter-particle background by a uniform color;
(3) for each juvenile fragment, blacken the vesicles and repair most of the cracks;
(4) for each juvenile fragment, optionally improve the contrast between different internal features such as crystals versus groundmass.

The present user guide details these SEM-BSE image preparation steps, which involve both manual operations and as much automation as possible using batch processing and a

Photoshop action pack. The procedure has been developed and tested with Adobe Photoshop© on SEM-BSE images obtained from particle cross-sections using polished epoxy grain mounts, and is not guaranteed to work with other image types or with other software.

Image preparation in Photoshop© consists of five main steps, described in detail below:

i) First, a batch processing step converts each original multi-particle uncompressed image into an editable Photoshop file (.psd), characterized by a white, partly transparent top layer called the "form layer", representing the particle area, overlapping the original image;

ii) Second, the form layer of each image is manually refined in order to accurately depict the particle shape;

iii) Third, for each image, the user manually selects the juvenile particles to be analyzed, and the inter-particle area is automatically converted to a homogeneous RGB color required for processing. There is then an option, within the action, to improve the greyscale contrast between the crystals and the groundmass by adjusting the levels, if needed;

iv) Fourth, the internal texture of each particle is manually refined by blackening vesicles and repairing most cracks, in order to later obtain an accurate measurement of crystallinity and vesicularity in Fiji;

v) Finally, the refined .psd files are batch converted into uncompressed color images (TIFF).

Setting up the folder system

First, on your computer, create the folders required to store a backup of the files used and generated during each step. Template folders for Microsoft Windows® machines are provided in the "Windows Template Folders" located inside the main package folder on

GitHub. In what follows, folder paths and labels will correspond to those provided in the package.

To optimize image preparation, place the input files called for during each step into the folder BATCH_TEMP\INPUT. After each step involving an automated action (i.e., steps 1, 3 and 5), output files will be generated in BATCH_TEMP\OUTPUT. In order to avoid potential loss of data, always work on copies of the original files, creating backup copies in the respective backup folders provided at the end of each step. For the manual steps, we recommend to work on the files directly placed in BATCH_TEMP\INPUT, therefore ready for the next action to run.

Initial setup of Photoshop workspace

If using batch processing in Photoshop for the first time, manually set up the workspace to optimize the procedure. First, from the menu bar, go to Window → Workspace and set the workspace to "Graphic and Web". Still from the "Window" menu of Photoshop, select the "Actions" and "Channels" tabs to display them in the workspace. Finally, in the "Actions" tab, load the action pack named *Image Prep_v3.1.atn* from the "Image Preparation_Photoshop" subfolder, as shown in Fig. 1.

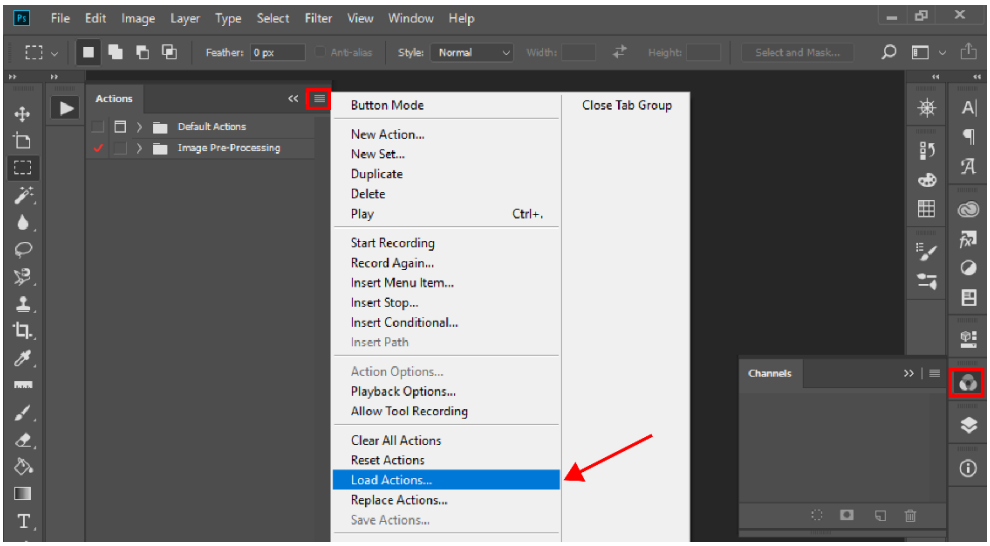

Fig. 1 Loading the action pack from the "Actions" menu. The red square on the bottom right indicates the "Channels" tab icon.

Step 1 – From original SEM-BSE images to editable .psd files

Overview

The Photoshop action pack allows this step to be executed automatically, batch processing all the images in the input folder. The action first converts the input TIFF images to 8-bit .psd greyscale, if needed. Next, a temporary 45% opacity-white "form layer" (i.e., Layer 1) is automatically generated, corresponding to the area of each particle. This layer is obtained by the selection of 100% black pixels from the inter-particle background, then inverted to select the particle edges, using a single (1 pixel) expansion-contraction operation on the image selection (Shea et al. 2010). This sub-action will discard most of the unwanted inter-particle noise and debris while preserving the roughness of the particle edges (manually accessible from the menu found in Select → Modify → Expand…/Contract…

Instructions

To execute this step, first manually place a copy of your source SEM-BSE images (e.g. all the images for a specific sample and size fraction) inside the BATCH_TEMP\INPUT folder. Next, in Photoshop, go to the File menu and open the image processor:

File → Scripts → Image Processor

In the image processor tab (Fig. 2), under (1), select the BATCH_TEMP\INPUT folder. Under (2) tick the "keep folder structure" box and select the BATCH_TEMP\OUTPUT folder. In (3) select only "Save as PSD" and tick the "Maximize Compatibility" box. In (4), select "Run Action" and choose "Original_to_PSD_Light_Juv" as default. Tick the "Include ICC Profile" box, then click on "Run" to proceed.

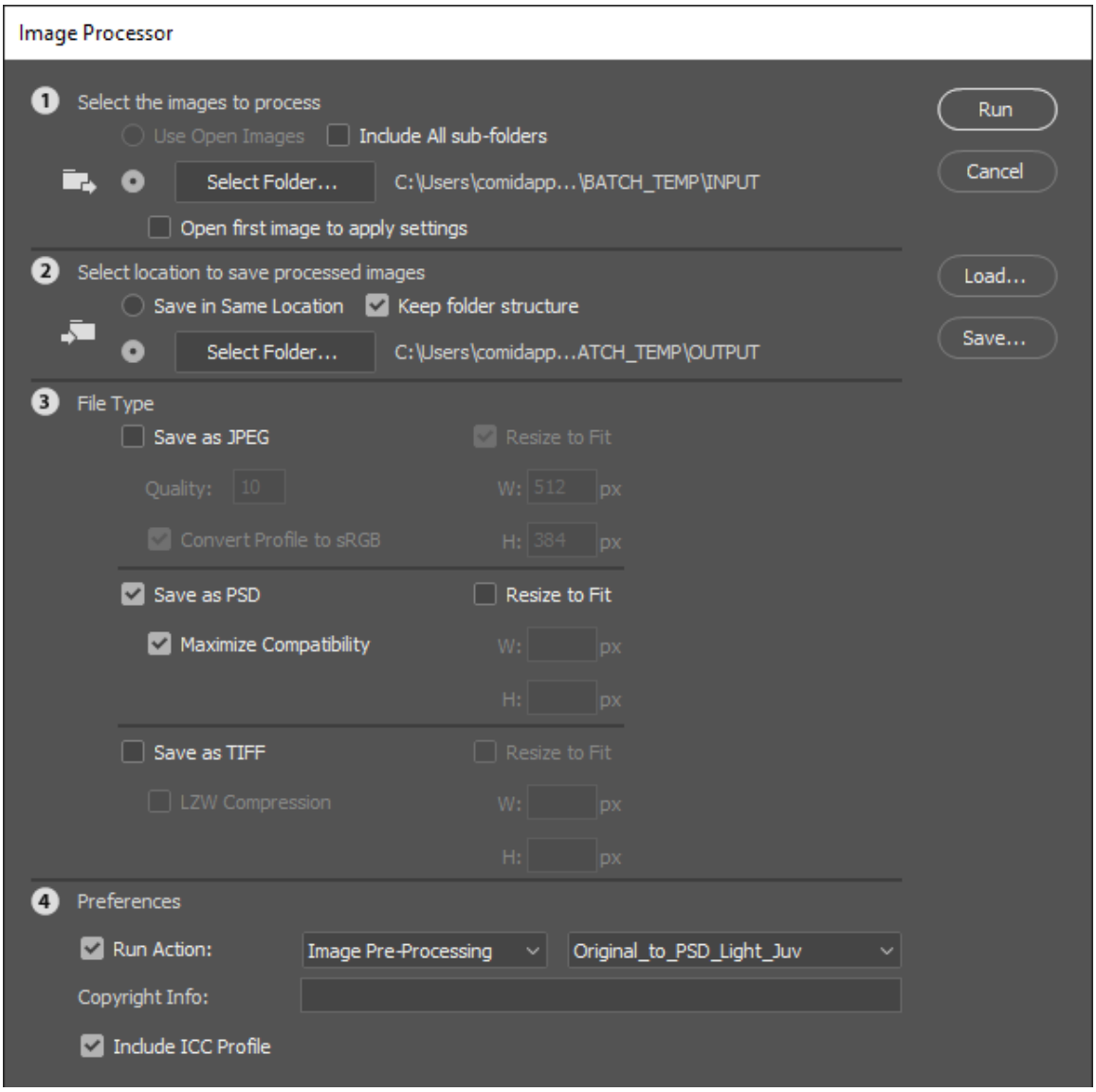

Fig. 2 View of the Image processor tab.

Do not perform other tasks while the action is running, to avoid system crashes or freezes. If the particle cross-sections are too dark, the default action ("Original_to_PSD_Light_Juv") might not detect the particle edges correctly. In this case, use the action

"Original_to_PSD_Dark_Juv" instead. Once this step is finished, create a backup copy of all the .psd files into

Pre-processing_Photoshop\1_PSD_Form_Unrefined

Step 2 - Manual refinement of the particle area

Overview

This step allows you to manually refine the particle edge, correcting any inaccuracies produced by the automated action in step 1. It commonly involves "removing debris" misinterpreted as the particle edge, and closing vesicles located near the particle edge (Fig. 3). The idea is that the user interprets these vesicles to have originally been completely enclosed inside the particle, rather than forming part of the perimeter, but thin vesicle boundaries may have been damaged during polishing.

Instructions

To start, place a copy on the .psd files in BATCH_TEMP\INPUT. Open the first .psd file. Working on "Layer 1" (the temporary "form layer"), manually refine the particle edge overlay using the "Pencil tool" (B key). Use a black color to remove unwanted pixels from the juvenile particle and the white color to add pixels (Fig. 3). Select 100% hardness and 100% opacity, adjusting the diameter of the brush as convenient (Fig. 4). The smoothing function allows to control the shakiness of the hand while contouring a detail. Repeat this form refinement for each .psd file, then save a backup copy of all refined files in

Pre-processing_Photoshop\2_PSD_Form_refined

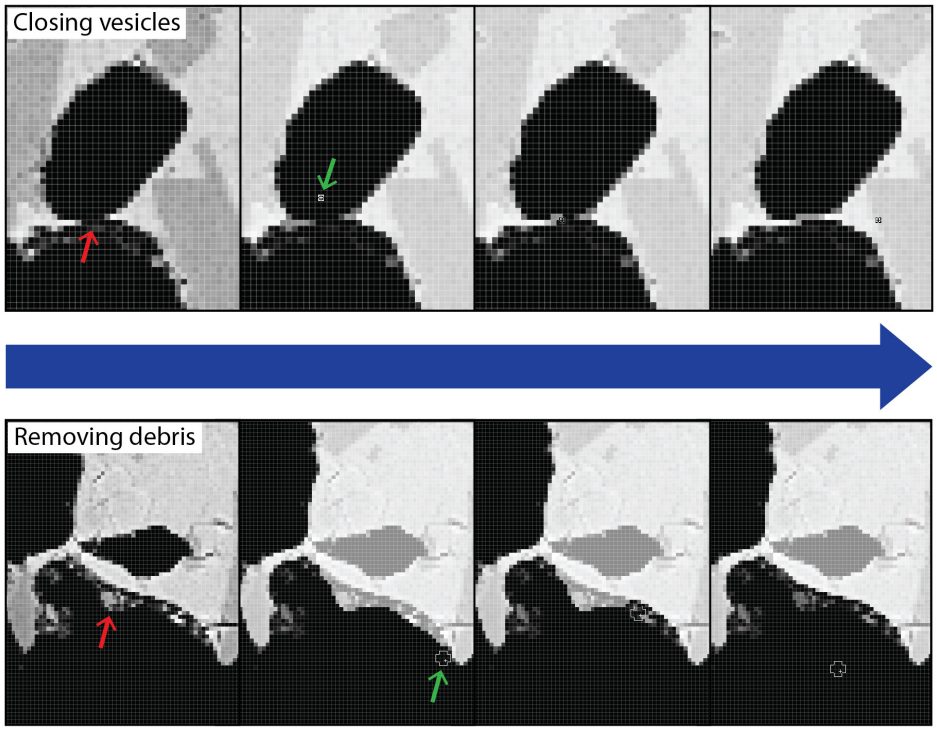

Fig. 3 Sequence of images (from left to right) depicting the refinement of the particle "form" overlay. The first image (from the left) of each sequence row shows the image without the semi-transparent "form" overlay. The red arrows indicate a vesicle (top) and adhered debris (bottom) misinterpreted as particle edge. Green arrows show the size and appearance of the mouse cursor when using the pencil tool.

Tips

i) Always check that hardness is at 100%, as a lower value will prevent the action to work correctly on the next step; ii) Refrain from doing any unnecessary extra refinement on the images (e.g., removing grains touching the edge or cleaning the inter-particle area from the image "Background" layer), as the next step will take care of it.

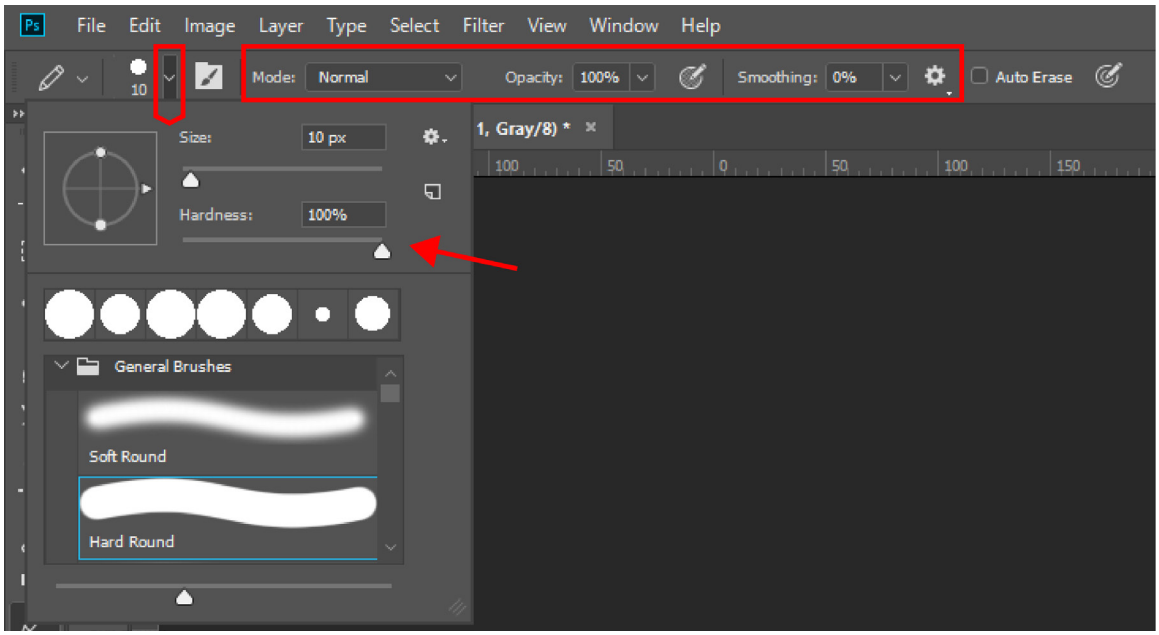

Fig. 4 Settings for the pencil tool. Size and smoothing can be adjusted to purpose.

Step 3 – Particle selection and inter-particle area refinement

Overview

This step is semi-automated, allowing the user to select only the wanted juvenile particle cross-sections to be processed. The action uses the temporary "form layer" overlays of the selected grains as a base selection to "clean" the rest of the overlay, removing particles touching the edge of the image, lithic fragments, debris and dust, etc. The new clean selection of the inter-particle background is applied to the actual image, which is filled using a homogeneous, RGB blue background (R: 100; G: 160; B: 220). Finally the "form layer" is deleted along with the "form selection" channel. Optionally, the contrast of the image can be improved to better distinguish different crystal phases from the glass groundmass.

Instructions

To start, open a .psd file (already located in BATCH_TEMP\INPUT). From the "Tools panel" of Photoshop, select the "Magic Wand tool" (W key) in "add to selection" mode. Set the tolerance to 50, tick "Contiguous" and select other settings as shown in Fig. 5.

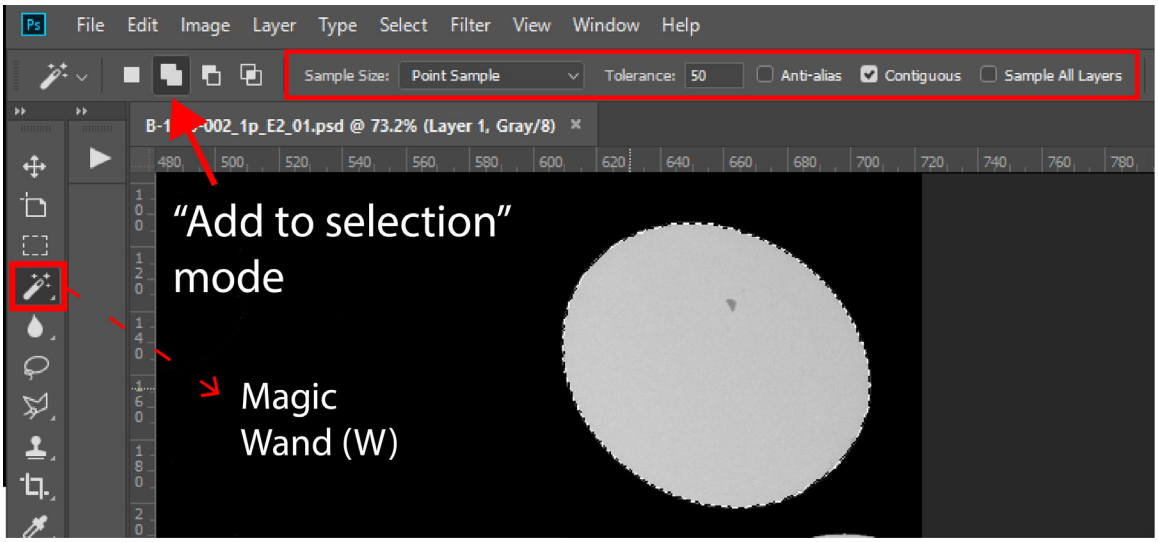

Fig. 5 Particle selection in step 3. Settings for the wand tool are highlighted by the top red rectangle.

Working on "Layer 1" (the temporary "form layer"), select all the wanted particles with the Magic Wand. Once done, run the action "ClearBKG_FillHolesColorBKG" from the "Actions" menu by pressing the "play" button highlighted in Fig. 6. Alternatively, and to work faster, you can set up a keyboard shortcut for the action (e.g., the F2 key) from the "Actions" menu under "Action options", while the action is selected.

This action uses the current particle selection overlay to clean the inter-particle area. The overlay is first filled with 100% black, then the selection is inverted on the particles, filled with a 100% white color. The cleaned inter-particle area selection is then transferred to the actual image (i.e., the "Background" layer), and filled with the blue color (image is converted

from 8-bit greyscale to RGB type format). Ultimately, the "form" layer is deleted along with the associated channel selection.

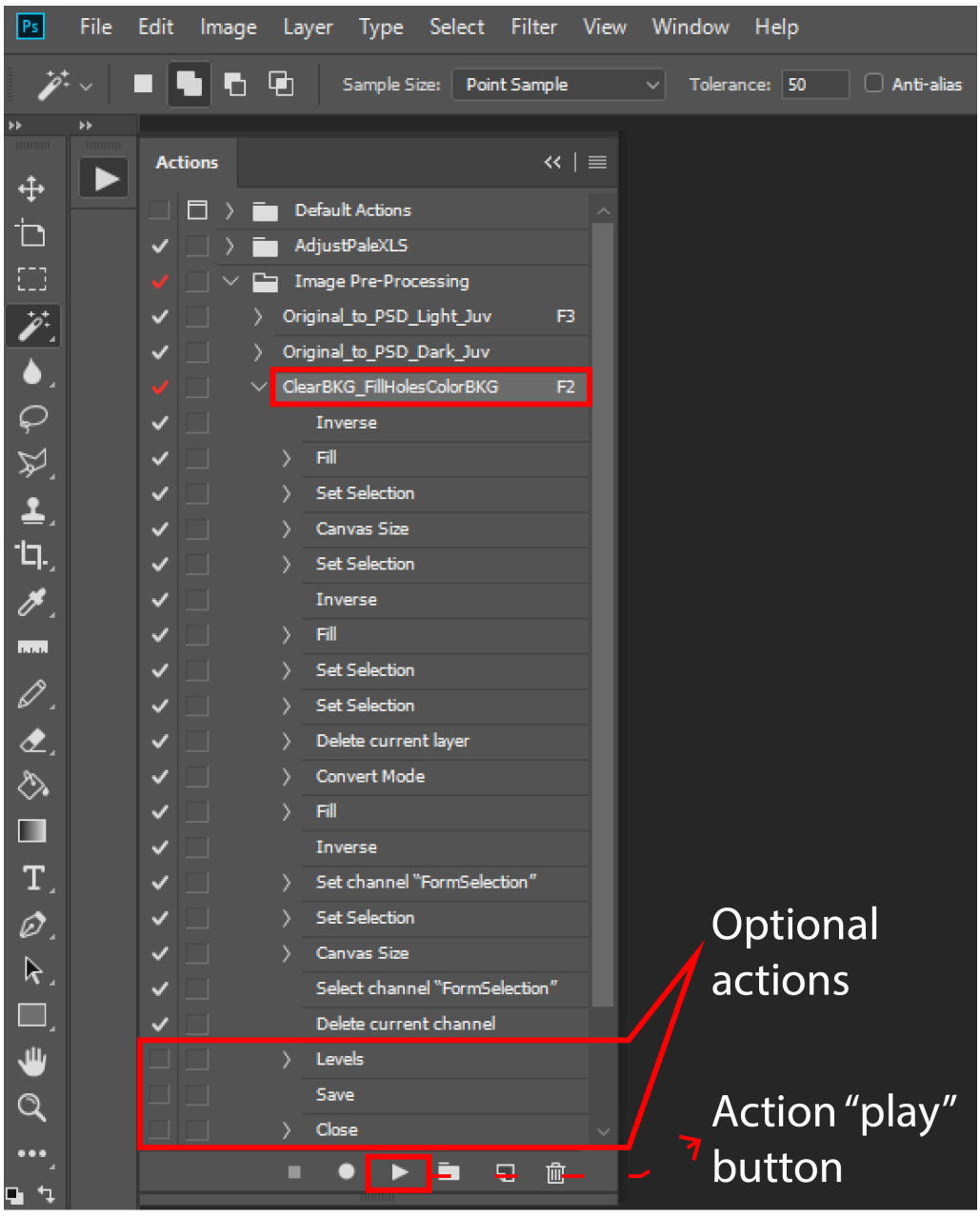

Fig. 6 View of the "ClearBKG_FillHolesColorBKG" action in in step 3.

To improve the contrast among the internal features of the particle, such as crystals phases versus groundmass, tick the "Levels" box before running the action (Fig. 6). This sub-action is optional and should be activated only if the images are poorly contrasted. Furthermore, once applied to one image, the "Levels" sub-action ***must*** be applied to the whole stack of files to be processed.

The last two sub-actions at the bottom of the action allow to automatically "Save" and "Close" the currently processed file. Since these actions are irreversible, the user is reminded to always work on copies of the files. Repeat step 3 on the whole stack of files, then create a backup copy of the output files in

Pre-processing_Photoshop\3_PSD_Blue_BKG_UNrefined

Step 4 - Manual refinement of the internal texture

Overview

Step 4 allows the manual refinement of the internal texture of each juvenile fragment. Details such as particles touching each other, cracks, non-black vesicles or debris-filled vesicles are fixed within this step, using several editing tools highlighted in Fig. 7.

Instructions

Create a copy of the unrefined blue background .psd image files in BATCH_TEMP\INPUT, then open the first one. To separate touching particles (required to guarantee successful particle isolation during image processing in Fiji), use the "Lasso tool" (L key) to contour and separate touching particles. Use the "bucket tool" (G key) to fill the pixels generated upon displacement, applying the same blue than the inter-particle area generated in step 3. To blacken the vesicles, use the "pencil tool" (B key) with the black palette, 100% hardness and 0% smoothing (Fig. 8). To fill cracks, use the "Clone Stamp tool" (S key) with 100% hardness and opacity (Fig. 8). Holding the "Alt" keyboard button

while clicking on a detail to clone will copy the detail that can be pasted by simply clicking on the desired point. The use of keyboard command shortcuts is highly recommended in order to speed up the process. Holding "Alt+right mouse click" (on Windows) while shifting the mouse cursor left or right, you can respectively decrease and increase the size (in pixels) of the selected tool. Repeat this step for all the .psd files, then create a backup copy in

Pre-processing_Photoshop\4_PSD_Blue_BKG_refined

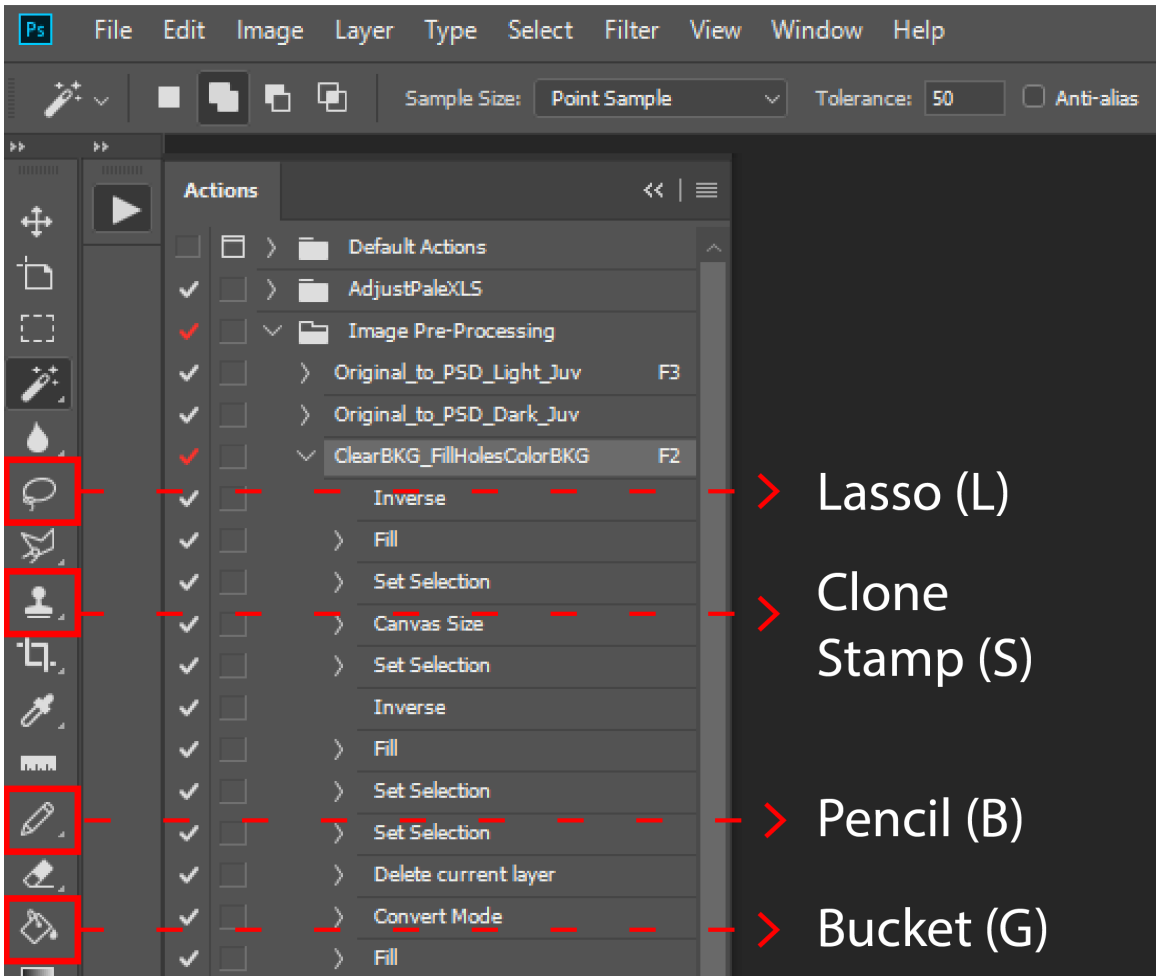

Fig. 7 List of editing tools for internal texture refinement in step 4.

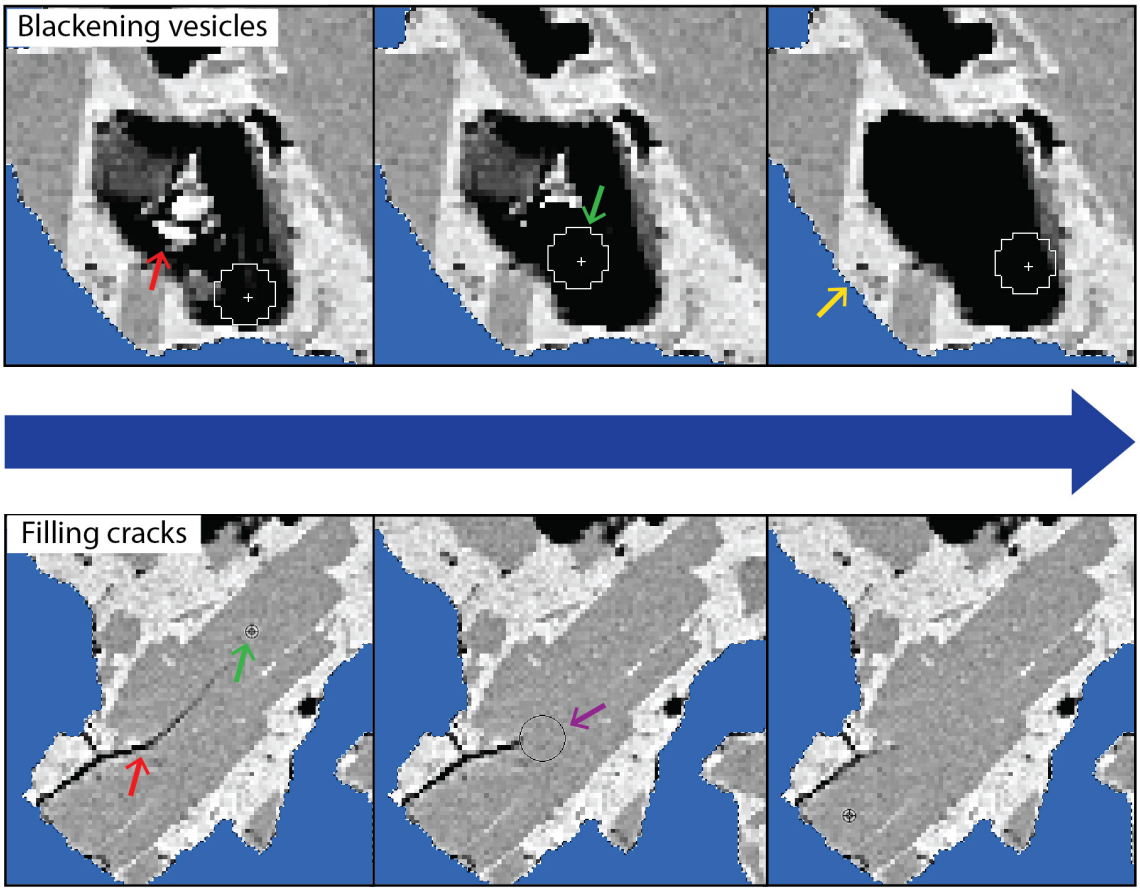

Fig. 8 Sequence of images (from left to right) depicting the refinement of the internal texture. Top: the red arrow indicates a vesicle to be blackened. The green arrow shows the size and appearance of the mouse cursor when using the pencil tool. The yellow arrow highlights the flashing dashed line on the particle edge indicating the presence of an active selection. Bottom: the red arrows indicates a crack to be filled within a crystal. The green (clone) and purple (stamp) arrows show the size and appearance of the mouse cursor when using clone stamp tool.

Step 5 - Convert refined Photoshop files into TIFF images

Overview

The last step is entirely automated, and operates the conversion of the refined .psd files back into uncompressed images in .tiff format.

Instructions

With a copy of the refined .psd files already in BATCH_TEMP\INPUT, open the "Image Processor" (Fig. 2). Set (1) and (2) as described in Step 1 (by default it should be already set, as it will keep the last folder path inserted), then in (3), select only "Save as TIFF" (make sure LZW compression is deselected). In (4), deselect "Run Action" (include ICC Profile). All .psd files will be batch converted into color TIFFs, suitable for use in Fiji using the PASTA code. Once finished, close Photoshop.

References

Comida PP, Ross P-S, Dürig T, White JDL, Lefebvre N (2022) Standardized analysis of juvenile pyroclasts in comparative studies of primary magma fragmentation; 2. Choice of size fractions and method optimization. Bull Volc https://doi.org/10.1007/s00445-021-01517-5

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